EXHIBIT 4

Preliminary Technical Report: SBI vs. Whinstone

Technical Expert Findings

Submitted by: Charles C. Byers

March 27, 2025

1 EXECUTIVE SUMMARY

This technical report covers observations, findings and analysis of a large-scale datacenter about 6 miles southwest of Rockdale Texas on Charles Martin Hall Rd. The datacenter is owned by Whinstone (now part of Riot Platforms, Inc.), and housed 20,000 specialized cryptocurrency mining computers owned by SBI Crypto between November 2019 and June 2021.

There were significant performance concerns and poor mining productivity observed during this installation. This report will show these performance deficiencies were caused by problems with the design, construction, commissioning, operation, management, monitoring and ongoing maintenance of this datacenter by Whinstone, resulting in significant economic losses to SBI.

I conclude the following are major causes of the performance problems, as detailed in this report:

- Environmental conditions in the Whinstone datacenter caused the poor bitcoin mining productivity and unacceptably high failure rate of the SBI miners;
- The datacenter building and its site have significant design and construction errors, leading to poor operational environment for the miners;
- The design of the cooling system that relies on wet curtain walls is inadequate for the thermal density created by the miners, leading to severe overheating and widespread failures;
- The wet curtain walls were not operated during the times when the SBI miners were installed, causing input air much hotter than the 29.5°C limits stipulated in the contract, and greatly exceeding the thermal specification limits of the miners;
- Dust contamination is a significant problem, caused by Whinstone's failure to provide air filters and adequate cleaning practices, leading to miner failures;
- Whinstone failed to maintain adequate seals between the hot and cold aisles of the datacenter, creating significant recirculation of hot air and leading to miner overheating;
- Failed miners were not detected and repaired promptly as required by the hosting contract, leading to poor miner fleet performance and certain cascade failure modes;
- There were significant problems with input power monitoring and power interruptions that negatively impacted the uptime of the miners, and therefore their productivity;
- Whinstone should have provided better monitoring, logging, control and correction of the environment inside the datacenter, in accordance with accepted industry best practices;

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5 INTRODUCTION

5.1 PURPOSE

This expert report covers technical analysis of certain problems encountered in the array of 20,000 crypto mining machines owned by SBI Crypto, Inc., and installed in the Whinstone Rockdale, Texas, USA datacenter. It will analyze the physical, electrical, network and environmental conditions before and during the operational period of those miners, and describe various shortcomings of the datacenter,

their impacts on the electronics in the miners, the contribution of poor miner reliability to the profitability of the installation, and their probable root causes.

5.2 Scope

This report concentrates on the installation of 20,000 large-scale bitcoin mining machines owned by SBI and hosted in Building B of the Whinstone Rockdale, TX datacenter. It covers the planning, construction, build-out, and configuration of the building, and the planning, installation, configuration, commissioning, operation, maintenance, repair and decommissioning of the miners. The data covers events occurring on dates that span from approximately April 2019 through September 2021.

5.3 Expert Qualifications

Charles Byers is the chief technical officer of Industrial Internet Consortium (IIC) and formerly served as principal engineer for Cisco and a Bell Labs Fellow at Alcatel-Lucent. He has more than 35 years of experience in computer engineering and specializes in developing the architecture for common platforms and data processing systems.

5.3.1 Experience

- CTO of Industry IoT Consortium 2018-Present; Leading the technical efforts of an organization of 100+ member companies working on digital transformation, efficient AI, trustworthy IoT, digital twins and standards;
- Principal engineer at Cisco from 2008 to 2010; assisted in research projects relating to high-power servers, advanced air cooling and liquid cooling;
- Bell Labs Fellow at Alcatel-Lucent 1986-2008, working on networks and central office / datacenter equipment design;
- Primary architect of the Advanced Telecom Computing Architecture standards at PICMG, a high-density modular platform for computation and networking with significant thermal and lifespan challenges;
- Assisted in a multi-month consulting project for LiquidCool Solutions, a manufacturer of liquid cooling infrastructure, which included advanced crypto-miner cooling concepts;
- Completed nearly 100 short-term consulting projects in areas related to datacenter cooling, power, interconnect, IT equipment, semiconductors, optics, software, blockchain and AI;
- Holds over 130 issued US patents, and several more pending, including about two dozen related to cooling high power computing and networking equipment;

5.3.2 Litigation Support Summary

Cases: 6 Depositions: 2. Mr. Byers has served as an expert witness primarily in patent litigations, including one regarding high-performance optical systems with thermal control and reliability implications. He has provided expert reports and been deposed, but not during the previous four (4) years. Mr. Byers has not yet had the opportunity to testify at trial.

5.3.3 Education

B.S. in Electrical and Computer Engineering and M.S. in Electrical Engineering from the University of Wisconsin

5.3.4 Publications and Conference Presentations:

- IIC Journal of Innovation: "Responsible Generative AI" March 2024;
- IIC Journal of Innovation: "IoT Techniques and Elements for Drone Package Delivery" August 2023;
- IIC Journal of Innovation: "Key Criteria to Move Cloud Workloads to the Edge", and "Heterogeneous Computing in the Edge" June 2021 https://www.iiconsortium.org/journal-of-innovation/ ;
- Global Industry Organizations (China): AI for Manufacturing Roundtable" September 2023;
- Digital Manufacturing Summit North America: "Trustworthiness of Complex Systems" June 2023;
- Smart Manufacturing World Summit: "Edge Computing: A Leading Driver for Digital Transformation in Manufacturing" October 2022;
- Edge AI Summit: "Partitioning Machine Vision AI Workloads Across the Cloud – Edge – Intelligent Device Hierarchy" September 2022;
- UAS Summit & Expo 2021: "Drone Delivery: Revolutionizing and Innovating Traditional Logistic Solutions" ;
- Edge Computing World Conference 2022, 2021, 2020 and 2019: gave keynotes and tutorials introducing edge computing;
- IoT Evolution Expo Conference in 2022, 2019, 2018, 2017, 2016, 2015, and 2014: Gave presentations, lead tutorials and moderated panels on IoT, fog, drones, security, use cases and architectures;
- Fog World Congress 2018, 2017: Presentations on fog architecture, design tips, panels, and program committee;
- Sensors and IIoT Conference: "Trustworthy IoT" April 2021;
- IEEE Communications Magazine: "Architectural Imperatives for Fog Computing: Use Cases, Requirements, and Architectural Techniques for Fog-Enabled Networks", Volume 55, Number 8, August 2017;
- Mobile Edge Computing Congress (Munich): "Fog Computing in a MEC Environment" September 2016;
- Association for Computing Machinery Ubiquity Journal: "Fog Computing: Distributing data and intelligence for resiliency and scale necessary for IoT" Ubiquity, an ACM publication, Nov. 2015;

5.3.5 Compensation

$590 per hour for all work and travel time. Work away from home location is billed in eight-hour increments.

My complete CV is available in this reference.[1]

5.4 Overview of Study Methodology

This report considers evidence of the operational performance of the SBI bitcoin miner fleet under the conditions provided at the Whinstone Rockdale datacenter. Evidence was collected from various sources, correlated to verify its significance and reliability, and analyzed in detail. Situations where the operation of the Rockdale datacenter depart from industry accepted practices or from the terms of the hosting service agreement for the Rockdale datacenter are noted and analyzed for their significance and effect on the performance of SBI's miners. Chains of causality for substandard equipment performance

are described and followed to their probable root cause(s). Specific acts or omissions by Whinstone are outlined, and their impact on equipment performance and reliability are analyzed.

Some of the content of this report resulted from collaborations with others familiar with the facility and the miners at issue, including Phil Isaak (expert on cooling and datacenter environments) and Carson Smith (former CEO of SBI Crypto). Some analytical laboratory reports are also included.

5.4.1 Data Sources

The data analyzed here is largely based upon evidence gathered from various interactions between SBI, Whinstone, and partner companies, field observations from datacenter site visits, depositions, and performance statistics recorded from the miner fleet. The author has access to the complete discovery database of Winstead PC.

The first set of data sources are a series of negotiations between SBI and Whinstone that led up to the signing of a Hosting Service Agreement (amended).[2] A series of email and text communications[3] document the many challenges associated with completing Building B of the datacenter, outfitting it to be ready to accept the SBI equipment, and installing / commissioning the miners. Once the miners were operational, further interactions describe problems related to miners overheating and underperformance issues.

Another set of data is the operational logs and mining productivity results from the fleet of miners. This data outlines the negative performance impacts of the conditions in the Whinstone datacenter. A particularly important source of data is an extensive datacenter telemetry database collected by Lancium (the company responsible for optimizing the electric power usage of the miners). Other sources include electric bills, and various status and mining reports.

5.4.2 Field Research

Data was collected on a site visit in June 2021 by Nick Foster of Kaboomracks and an inspection of Building B by Phil Isaac in November 2024. Photos, video and observation notes were collected both inside and outside Building B, and also in various maintenance and storage locations on the site. These include important insights into the conditions in the datacenter, and the steps Whinstone may or may not have taken to improve the reliability and performance of the SBI miner fleet. I also performed various types of failure mode analysis and teardown of SBI equipment removed from the datacenter.

5.4.3 Analysis

The data and field research from the time intervals when the miners were active at Rockdale were collected from the discovery phase, and analyzed by technical experts. My analysis described the observed conditions and performance statistics, and attempted to understand why these miners were performing so much worse than identical miners installed in another datacenter located in Russia. The evidence pointed to problems related to the design, configuration, installation, operation, management, and maintenance of the Rockdale datacenter and the SBI miners operated there, especially related to the air cooling subsystems and dust contamination. Comparisons are made between the operational conditions at the Rockdale datacenter, industry best practices, and similar datacenters in Russia.

Data from the analysis of the evidence and field research is presented and analyzed in the remainder of this document. As specific items of evidence are referenced in the body of the document, endnote

citations will be designated by superscripted reference numbers. Pointers to those references (usually file names or URLs) can be found in Section 7.

6 INTRODUCTION TO DATACENTERS

Datacenters are centralized collections of information technology equipment, housed in a building, and provided with the power, cooling, networking and support infrastructures needed to run them reliably and efficiently. These support infrastructure elements include supplying reliable electric power of adequate quality, adequate cooling capacity to keep the systems below their operational thermal limits, network interconnection with sufficient bandwidth to connect each piece of equipment to other equipment in the datacenter and the external internet, and monitoring / management / maintenance systems and procedures to configure, monitor, diagnose, repair, update and maintain suitable operational environments for the systems. This section outlines some key concepts and best practices related to datacenter design and operation. Subsequent parts of this document will contrast conditions and practices observed in the Whinstone Rockdale datacenter with these best practices. Many resources are available to describe datacenter design.[4]

Some datacenters are general purpose, able to host any configuration of data processing equipment, while others (such as the building under discussion in Rockdale, TX) are optimized to best serve a specific task, such as general internet servers, artificial intelligence, scientific computing or highly specialized applications like crypto currency mining.

Figure 1 - Datacenter Architecture depicts a stylized view of the architecture of a typical datacenter that could be used for hyperscale cloud services, high performance computing or crypto mining. The primary components are the servers in the server racks on the right, including circuit boards with various types of processing chips, storage modules and network interfaces. The rest of the equipment on the diagram supports the servers with power, cooling, interconnect and management infrastructures.

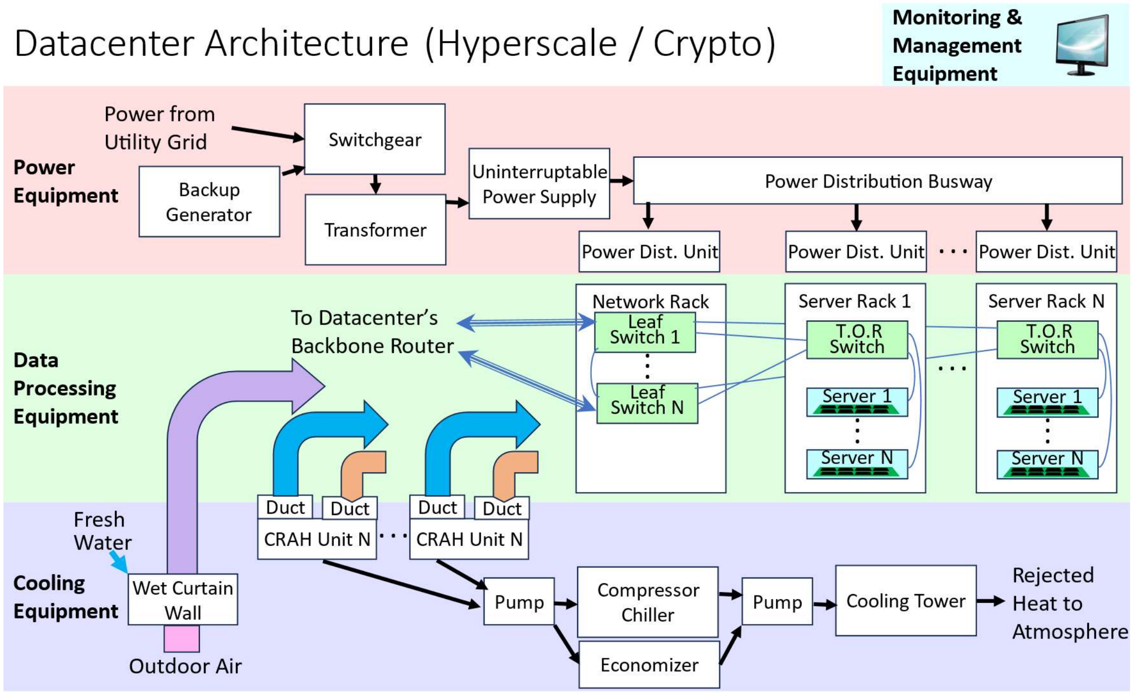

Figure 1 - Datacenter Architecture

6.1.1 Chips

Semiconductor integrated circuits (or chips) are at the heart of every piece of data processing equipment. Each chip can contain from a few hundred to over 200 billion individual transistors. They are created in some of the most complex, expensive factories in the world (called wafer fabs), encapsulated in plastic or ceramic packages, and rigorously tested before being sold to customers to be soldered onto circuit boards. Many companies (called fabless semiconductor companies) design and sell the chips, but rely on external wafer fabs (including giant companies like TSMC or UMC) for the complex semiconductor manufacturing. A few chip suppliers (like Intel) own their own fabs.

Several types of chips are common in data processing equipment, including conventional processors, Graphics Processing Units (GPUs), data network switches, memories, flash storage devices and Application Specific Integrated Circuits (ASICs). ASICs are specialized chips optimized to perform a fixed function very efficiently. Specialized crypto mining chips are one example of ASICs found in large numbers in certain datacenters.

6.1.2 Servers

Servers are a type of data processing equipment that provides the computing power in datacenters. They typically have one or more primary processing chips (such as processors, GPUs or ASICs), and the support circuitry (memory, storage, I/O, power conversion, management, etc.) needed to run them safely and efficiently.

In cryptocurrency mining, the most efficient servers (called miners) use ASICs in large numbers (typically hundreds per server) soldered in arrays to circuit boards, interconnected by control / communication boards, and powered by high-capacity power supplies. Because of the special design of the miner ASICs,

very high performance is achieved for comparatively little electrical energy use (although because of the large numbers of ASICs they run in parallel, some miners use several thousand Watts of power – similar to the power use and heat output of several salon-class hair dryers or the average power used by a few American households).

6.1.3 Racks and Mechanical Infrastructure

Data processing equipment is heavy and relatively fragile, so it must be supported in sturdy equipment racks. These racks provide mechanical support and physical protection, and can also have features to manage cooling. Sometimes the racks are mounted on a tile-grid raised floor that provides a space underneath to run cables, pipes and cooling air. Other datacenters bolt the server racks directly to a concrete slab and provide overhead racks to manage power, network cables and fiber optics.

6.1.4 Interconnect

The servers in a datacenter need to be networked so they can communicate with each other, and also broader computer networks. This is typically accomplished with electrical cables carrying Ethernet protocol (lengths up to 100 meters (328 feet)) or optical cables (longer lengths, up to 120 kilometers (75 miles)). The cables from a number of servers (typically several dozen to a few hundred contained in a rack) converge on an Ethernet switch (called a Top of Rack or ToR Switch) that combines their traffic onto a faster Ethernet. That faster Ethernet carries the combined traffic to one or more layers of higher order Ethernet switch or backbone router, typically located in a nearby network equipment rack or in a specialized networking room in the datacenter. This hierarchy of ToR switches and higher order networking equipment enables any server to efficiently communicate with any other server in the datacenter. It also connects all the servers in a datacenter to broadband access networks that transmit the datacenter's traffic to and from the Internet backbone, allowing the servers to communicate with users, data stores, control / monitoring systems and other resources anywhere in the world. These external broadband network links are usually carried over fiber optical cables between the datacenter and an internet access Point-of-Presence. Often, to improve resiliency, more than one cable connects datacenters to the internet backbone. Sometimes wireless or satellite backup connections are also provided.

6.1.5 Power Equipment

Massive amounts of electrical power are required to operate modern datacenters. This power is measured in Megawatts (millions of Watts of power) and the largest datacenters use 200 megawatts or more. One megawatt is enough electrical power to run about 800 average American homes. This power is typically generated by utility owned power plants employing fossil fuels, nuclear reactors, or hydroelectric dams, with typical capacity of 1000-6000 megawatts per power plant. These base load generators are often supplemented by renewable sources like wind turbines, solar photovoltaic and geothermal, but these are typically smaller in capacity and operate intermittently. A small percentage of electrical grid capacity is provided by geothermal, tidal, fuel cells and Battery Energy Storage Systems (BESSs). Power generation capacity in the US is tracked by the US Energy Information Administration.[5]

Power from these plants is boosted in voltage and enters the transmission grid, which consists of a number of long-distance transmission lines crisscrossing the country, switching centers and substations near customers that reduce the transmission voltage for consumer use. Transmission lines typically use voltages of 138,000, 230,000 volts or higher, which reduces resistive energy losses in the cables over the long distance. Local substations receive the energy from the transmission lines, and convert it to lower

voltages that are safer to distribute to local electric customers. Large datacenter customers often receive high voltage transmission lines and own their own substations to do efficient conversion to lower voltages on-site. Smaller datacenters usually use medium voltage (often 13,800 or 34,500 volt) power feed cables directly from one or more utility-owned substations. A 100-megawatt datacenter would draw somewhat over 7000 Amperes of electric current at 13.8KV, requiring many large diameter copper or aluminum cables to bring in the power. These industrial power systems use three phase power, where three different legs of AC power arrive with 120° phase difference between them.

The medium voltage entering a datacenter passes through power control equipment called switchgear. It distributes the power to various loads, automatically switches over to auxiliary generators (if provided) upon a power failure, and protects against overloads and other abnormal conditions. This reliable, conditioned power passes through local transformers that typically step it down to 120, 240 or 480 volts. The next step in many datacenters is an Uninterruptable Power Supply (UPS) that uses the incoming power to charge a large battery, which can be discharged to continue the operation of the data processing equipment if the grid has a brownout, voltage transient or failure. UPSs are often sized to run the load for a few minutes to a few hours, usually providing enough time to checkpoint and pause or relocate critical computational processes, or to start and synchronize the on-site auxiliary generators (typically arrays of diesel generator sets in the 2-megawatt each range). This type of generator burns about 270 liters (70 gallons) of diesel fuel per megawatt-hour produced[6] (around 650,000 liters or 170,000 gallons or fourteen 18-wheel tank trucks full of diesel fuel used per day for a 100MW datacenter), so large on-site fuel bunkers or a large fuel truck arriving every two hours could be required for sustained operation if extended utility interruptions are anticipated. Of course, datacenters without critical loads (which includes many bitcoin datacenters) don't equip UPSs or backup generators, and suffer the occasional service interruption if the utility grid fails.

The protected power from the UPS is distributed throughout the datacenter via breaker panels or structured power distribution systems called busways, and connected via cables to the equipment racks. The power is processed by a Power Distribution Unit (PDU) that monitors, protects and provides multiple connection points for all the data processing equipment in a rack to access the power. PDUs typically accept the three-phase industrial power, and separate it out to three single phase groups of outputs for use in most types of data processing equipment. More sophisticated PDUs provide detailed real-time measurements of the power flow and power quality characteristics delivered to each of their outlets, and report it to the monitoring and management equipment.

Power from the PDU is typically 120 or 240 volts AC, and enters each piece of data processing equipment via a short cable. That power is processed by a bulk Power Supply Unit (PSU) associated with each piece of data processing equipment that turns it into an intermediate voltage (often 12VDC or 48VDC). The intermediate voltage is distributed by internal busses to the boards in the equipment that carry the chips. The final stage in the power chain is a number of point-of-load power converters that step the intermediate bus voltage down to the specific voltages needed by each chip (often 3.3 Volts or an adjustable voltage near 1 volt, at very high current).

6.1.6 Cooling Equipment

Large-scale data processing equipment deployments in datacenters generate huge amounts of heat. Every Watt of electrical energy provided to a datacenter ends up as heat that must be removed from the data processing equipment. A megawatt of input power creates 3.41 million British Thermal Units

(BTUs) of heat load per hour, or requires 284 tons of refrigeration (the cooling capacity to freeze or melt 284 tons of ice in a day). The American Society of Heating, Refrigeration and Airconditioning Engineers (ASHRAE) has published guidelines and best practices for datacenter thermal design[7].

Many datacenters spend a significant proportion of their input energy on cooling, leaving less energy for a given power grid input capacity to run the data processing equipment. Power Usage Effectiveness (PUE) is a measure of the efficiency of a datacenter, defined as the total power drawn by a datacenter (including cooling and support equipment) divided by the subset of energy used by the data processing equipment. Typical hyperscale datacenters that use mechanical refrigeration to cool equipment could have PUE in the 1.3-1.5 range. Datacenters that use alternative technologies like total immersion liquid cooling or evaporative curtain walls can have PUEs of 1.05 or better, meaning that only 5% of the input energy is used for cooling, with 95% available for running the data processing equipment. Lowering PUE is one of the best ways to make datacenters cheaper to operate, and also reduce their potential environmental impact. Operational / energy efficiency is a key to success in high volume / low margin computation like bitcoin mining, but the quest for better operational efficiency can't come at the expense of meeting performance or reliability requirements.

The task of datacenter cooling infrastructures is to absorb the concentrated heat generated by the chips inside the data processing equipment, and reject it to the outside environment. Heat must be removed at a sufficient rate to prevent the semiconductors in the chips from exceeding their operational temperature recommendations (often 70-85°C or 158-185°F). If the semiconductor junctions exceed their rated temperature, they suffer many problems, including reduced life / more frequent failures (according to Texas Instruments, every 10°C (18°F) increase in chip temperature can reduce the life of the chip by 50%)[8], slower logic performance / logic threshold voltage changes (that can lead to system errors), additional power draw (that can lead to thermal runaway situations), and surfaces on the equipment that are unsafe to touch. Often, manufacturers of chips, servers or network equipment will refuse to honor warranties if the chips were thermally abused. Datacenter best practices are to maintain the input temperature of the cooling systems of all equipment below the manufacturer's recommended maximum coolant inlet temperature at all times.

Chips create heat as a result of interactions of flowing electrons with atoms in the semiconductor crystals as the internal transistors switch on and off and signals travel through the microscopic conductors in the chips. There are ways the chips can be designed to reduce this heat generation, but any chip that does useful work is going to generate heat. As chips run faster and include more transistors, heat can rise quickly, with the most power intensive chips available in 2025 (for example the Nvidia Blackwell GPU) using 1200 Watts[9] (about the same power as a salon grade hair dryer). ASICs are generally lower power, with a typical bitcoin miner ASIC using 10-20 Watts (like a small lightbulb), but individual miners could contain hundreds of ASICs. The heat generated in the transistors moves into the semiconductor chip, and out through the chip's package to the cooling system. Several layers of thermal resistance impede the heat movement from the transistors to the die, to the package, to the heatsink, to the coolant, and finally to the heat rejection system. With temperature deltas at each layer due to the thermal resistances that add up and must be overcome, the external environment to the chip must be kept significantly cooler than the allowable temperature of the semiconductor junctions for the cooling system to be effective.

At this point, several methods of heat removal can be used. The most common method is forced air cooling, where a heatsink (often made out of aluminum) is attached to the top (and sometimes also the bottom) of each chip, and the heat from the chip's package is conducted up a number of thin fins and onto a large area of heat transfer surfaces. Airstreams blow through the fins of the heatsinks, removing the heat from the heat transfer surfaces via convection as fast as the chip generates it, achieving thermal equilibrium. An alternative system replaces the finned heatsink with a device called a cold plate. Chilled liquid coolant circulates within the cold plate, efficiently removing the heat from the chip. Yet another method involves total immersion cooling, where the entire circuit board, chips and all, are immersed in a special dielectric (nonconductive) fluid that surrounds the chips on all sides, and removes the heat to the bulk coolant, which is circulated through cooling systems. Some liquid cooling systems use single phase coolants (based upon water or oils), while others use two phase coolant with more complex chemistries designed to boil at a certain temperature, removing more heat from the chips.

Once the heat from the chips is transferred to the coolant (either air or liquid), it must be moved out of the data processing equipment and the racks that contain it. In air cooled systems, high-capacity fans typically suck cool air into the front of a rack, and blow hot exhaust air out the rear. In liquid cooled systems, the chilled coolant enters the rack on one set of pipes, passes through the cold plated or immersion tanks, and the hot exhaust coolant exits a second set of pipes. Ducts and manifolds direct, split, separate, monitor and control both hot and cold coolant flows.

Once the hot coolant (air or liquid) is out of the rack, it must be managed so it doesn't interfere with chilled coolant supplies. In air cooled systems, hot / cold aisle sequestration is often employed, where physical barriers are installed to keep the hot exhaust air on one side of the racks from mixing with the cool supply air on the opposite side. In liquid systems, a device called a Coolant Distribution Unit manages and separates the flows.

In some systems, the sequestration baffles direct the air from the hot aisles to a device called a Computer Room Air Handler (CRAH) or sometimes a Computer Room Air Conditioner (CRAC) that accepts the hot air, and passes it over cooling coils. The resulting cold air is driven by a fan back to the cold aisle, and the cycle repeats using the same air.

The cooling coils in the CRAH unit require circulating chilled water to maintain their cooling capacity. This is generated by a cooling plant, that uses mechanical chillers (basically industrial air conditioners with many hundred horsepower (on the order of 150KW) motors in large datacenters) to generate the chilled water (usually around 10°C or 50°F) that is distributed to the CRAH units. The mechanical chillers remove the heat from the chilled water loop, and force it outside the datacenter where either a cooling tower (which evaporates water to aid the cooling process) or a dry cooler (which doesn't use water) rejects the heat to the atmosphere. In liquid cooled datacenters, the same chilled water from the chillers goes to a heat exchanger in the Coolant Distribution Units where it is used to chill the liquid coolant circulating to the cold plates or the coolant in the immersion tanks.

Alternative systems don't use mechanical chillers (which have large, expensive to run electric motors) or CRAH units, but instead try to do so-called "free cooling" where the heat from the chips is directly rejected to the atmosphere without the need for mechanical refrigeration. If the incoming outdoor air is cool enough (under about 30°C or 86°F), it can be directly routed to the heatsinks on the chips, and with careful design that takes into account all the temperature rises through the various thermal interfaces, enough heat is extracted to the flowing airstream, and the chips' junctions won't overheat.

However, if the design is inadequate because of inadequate airflow, incorrect heat sink sizing, dust accumulation, pressure problems or poor installation and maintenance (among other causes), the allowable semiconductor junction temperature will be exceeded, and the chips will malfunction. If the incoming outdoor air is expected to be hotter, a device called a wet curtain wall can sometimes be put on the building's air intake to make use of a process called adiabatic cooling. The cooling elements of wet curtain walls consist of a water distribution manifold on top, a labyrinth of porous media that the water saturates from above, horizontal air passages that expose the passing air to the wet media so the water is evaporated by the incoming airstream, and a trough below to collect any unevaporated water for recirculation. Depending upon the dew point / wet bulb temperature measurements of the incoming outdoor air, the air could be cooled 10°C (18°F) or more by the evaporation of the water from the curtain wall's media. Some locations have a favorable range of outdoor humidity and temperature enabling wet curtain walls to function. Unfortunately, many of these locations don't have access to the approximately million of gallons / several million liters of fresh water a large (100MW class) datacenter could need to evaporate every day. Other locations have too high expected ranges of temperature or humidity for wet curtain walls to function as adequately to maintain low enough cold aisle temperatures. This cooled (but more humid) air from the wet curtain wall passes through the data processing equipment (driven by powerful fans) and out the building's exhaust ducts, where the hot, humid air is exhausted to the atmosphere.

6.1.7 Monitoring and Management Equipment

Datacenters typically have large arrays of sensors to monitor parameters including temperature, airflow, humidity, coolant flow, pressures, voltages, currents, smoke, fire, flood, physical intrusion and many other parameters critical to building and infrastructure operation. These sensors are connected to building management systems that constantly watch for sensor readings out of acceptable ranges, and generate various types of alarms to alert maintenance staff to any corrective or repair actions that may be needed. In some situations, the alert is just a status light or indicator on the building control screen, other times it generates various audible alarms, pages, messages or emails to specified people. Occasionally, the building management systems are directly connected to actuators that can adjust the operations in the datacenter automatically without human interaction (for example cutting off water supply if flooding is detected, or starting evacuation fans if smoke is detected).

In addition, management systems are connected to most types of data processing equipment in the datacenter, allowing local and remote technicians to securely monitor the status and operation of any device. This monitoring is often a status display for the entire datacenter integrated onto one or more display screens, often called "single pane of glass" management. Devices with errors, not responding, experiencing overloads, or otherwise needing attention are flagged on the management display in recognizable ways. Should a device require attention, the management systems allow technicians to log into and modify the operational parameters of any device in the datacenter, for example, changing network configurations, adjusting fan speed, changing workload priorities, modifying security settings, or performing various types of power cycles, restarts and reboots.

Another function of the management system is software and configuration updates for the datacenter. Many tables of configuration and network routing data must be downloaded and maintained for each device in the datacenter. Software and firmware for the devices require frequent and sometimes urgent updates, especially to address emerging cybersecurity threats. Complex devices like servers or miners

can be updated individually, or in parallel groups. Good IT practices demand attention is paid to monitoring and updating all the devices on a nearly continuous basis, and any problems the management system detects with the building or the data processing equipment within are quickly addressed.

6.1.8 Datacenter Site Selection

There is a science to deciding the optimal place to build a datacenter. Although no location is absolutely perfect, there are some high priority attributes to preferred data center locations.

The first attribute, and the most important one to lifecycle cost is the availability of adequate electrical grid supply capacity at reasonable costs per megawatt-hour. Some locations are close to large-scale power infrastructures in a region, and if they have extra grid capacity, it is simpler to negotiate favorable long-term power purchase agreements for the number of megawatts needed. Large datacenters use tens of millions of dollars of electricity per year, and a location with low electrical rates and reliable grid connections is a key to profitable operation.

Datacenters need to have access to high-capacity fiber optical cables in order to connect them to the internet backbone. Ideally, two or more independent cables can be connected to each datacenter, so an incident that brings down one cable (storm, power failure, or digging it up with a backhoe) will not knock out connectivity to the entire datacenter. Those cables must have adequate capacity (often multiple fibers, each running at terabits per second) and terminate at internet points of presence adequate to support the expected traffic bandwidth and latency requirements to meet the data communication needs for the entire datacenter.

Regional climate is an important consideration. The hotter the average temperature is, the harder the cooling equipment must work to reject the heat from the data processing equipment. Wet curtain walls and cooling towers may not work efficiently if the temperature and/or humidity gets too high. If renewable sources are part of the datacenter's energy supply, the region must have adequate sunshine or wind resources. Considering the large investment in data processing equipment, it is desirable to select a location to minimize the weather-related risks that could cause serious damage, like hurricanes, tsunamis, wildfires, dust storms, tornados, floods, earthquakes, etc., excessive smoke, smog, dust, insect activity or salt spray can enter the datacenter or its cooling systems and foul airpaths or corrode surfaces, thus reducing cooling efficiency and leading to premature failure of the equipment.

If evaporative cooling is used (wet cooling towers or wet curtain walls) a large supply of fresh water is required. This water has quality standards similar to drinking water, because salinity or certain mineral or particulate content will deposit on the evaporative heat transfer surfaces, reducing their efficiency over time. It is important to maintain sterility of the water, as Legionella and other microbial contaminants have been a problem in some wet cooling systems, and water treatment chemicals to prevent microorganism growth must be used.

6.2 Introduction to Cryptocurrency Mining

Cryptocurrency is changing financial markets, and is getting a lot of attention – both positive and negative. It holds the possibility of decentralizing financial systems, decoupling currency from banks or governments, increasing financial privacy, and reducing the chances of currency manipulation.

The most prevalent of the hundreds of types of cryptocurrencies is Bitcoin. It was proposed in 2008 by Satoshi Nakamoto (a pseudonym – the true identity of the inventor of bitcoin is suspected but not known) in his famous paper: "*Bitcoin: A Peer-to-Peer Electronic Cash System.*"[10] It uses a distributed ledger type called a blockchain to store immutable records of transactions and ownership in a data structure called a block. Multiple blocks are chained together, allowing them to refer to each other in sequence to validate transactions. If more than 50% of the distributed blocks on the chain agree on a transaction, it is verified. It takes significant computation resources to add new blocks of records to the blockchain (done about every ten minutes) and to create new bitcoins (a process called mining). In addition to Bitcoin (BTC), two related types of cryptocurrencies that were "forked off" from the original BTC implementation are also considered important in this report: Bitcoin Cash (BTC), and Bitcoin Satoshi Version (BSV). The infrastructure needed to mine all three is similar. Many other cryptocurrencies beyond the Bitcoin family are commercially important, and use somewhat different blockchain and mining schemes (they are outside the scope of this report).

Operations on the blockchain are made deliberately computationally hard to prevent any one party with large computational resources to achieve the 50% control required to control the entire chain. These computations are called hashes, and use a specific crypto algorithm called SHA-256. The speed of performing these hash functions is called the hashrate (measured in terahashes (trillions of hashes per second) for miners, and exahashes (quintillions of hashes per second) for the global miner network). The Bitcoin algorithm periodically adjusts the difficulty of mining a block based upon how many miners are currently working, and how much bitcoin is left to mine. In early October 2024, the global hashrate was fluctuating near 700 exahashes,[11] and the best miner available at that time (Bitman Antminer S21 Hyd) could do 355 terahashes/s.[12] In 2021, the global energy used by bitcoin mining was estimated at between 91 and 150 Terawatt hours, similar to the power consumption of Finland[13]. The profitability of a bitcoin mining datacenter is dependent upon the current price of bitcoin, aggregate hashrate of the fleet of miners they have installed, its efficiency in using electricity, power costs per megawatt hour, hosting / management costs and their ability to keep the large fleet of miners operating reliability in a datacenter environment that optimally supports their power, cooling, interconnect and management needs.

The remainder of this section is a deep dive into the technologies of bitcoin mining chips, servers and infrastructure. It is necessary to grasp some of these concepts in order to understand the data in the following sections.

6.2.1 Mining chips

Crypto mining is a computationally intensive problem, but the algorithm for established cryptocurrencies doesn't change. It is possible to design efficient digital logic to perform the required algorithms using minimal silicon chip area and power. These hard coded circuits are called Application Specific Integrated Circuits (ASICs), and use only a fraction of the power and silicon chip area of a traditional programmable processor or GPU.

Miner ASICs contain large arrays (dozens to hundreds) of internal hashing engines working in parallel, each of which implements the SHA-256 algorithm (used in bitcoin, or similar cryptography algorithms used in other cryptocurrencies). Each engine has a few thousand to a million logic gates (AND, OR, XOR, INVERT, LATCH, etc.) made out of integrated circuit transistors implemented on layers inside the silicon chips connected together in a specific circuit pattern to accept inputs and automatically process hash values.

A typical miner uses large arrays of identical ASICs. For example, the Canaan model Avalon 1047 uses a total of 240 of a type of miner ASIC called A3205,[14] pictured in Figure 2 - Bitcoin Mining ASIC. These chips are based on a 16 nanometer semiconductor technology, which was a few steps below state-of-the-art for semiconductor fabrication when they were built in about 2018, but offered respectable performance, density and power efficiency. Each A3205 is capable of a variable hashrate of about .15 terahashes/s. A configuration option called "turbo mode" enables the hashrate to be significantly increased, at the expense of higher energy use and heat output. Each ASIC chip uses a variable amount of electric power (typically about 9 watts), depending upon the power supply voltage (which is adjustable +/- about 10%). They accept an input clock signal (that paces and synchronizes internal operation of the ASIC) whose frequency can be set within a range of allowable values (generally spanning about 10:1) using a timing circuit called a phase locked loop. Choosing a higher clock frequency increases hashrate, but also the power consumed by each chip, and the heat a miner produces. The exact power and hashrate can be controlled through an allowable range by adjusting the phase lock loop to provide different digital clock frequencies via a management interface as described in the user / installation manual.[15] Higher clock rates mean the internal mining engines compute faster. However, for the chips to operate reliably in the higher ranges of allowable clock rates, the input voltage to the core hashing engines, temperature and cooling must be carefully balanced. Each miner ASIC includes an internal temperature sensor that can monitor the die temperature of the silicon, and report it to external control and monitoring systems.

Figure 2 - Bitcoin Mining ASIC

For each miner ASIC, there is an optimal combination of clock frequency phase locked loop settings and ASIC power supply voltages to reliably mine the maximum bitcoin without drawing so much power that the miner overheats or the datacenter's available energy is exceeded. Because of manufacturing tolerances, the maximum achievable hashrate can vary between chips of the same type, so ASIC manufacturers test them by turning up the clock frequency until they begin to malfunction, back the frequency off a bit, and sort the resulting good chips into bins with similar maximum hashrates. ASICs of similar hashrate bins are often grouped together in specific product variants or performance grades. Miners using higher grades of chips cost more than superficially identical miners using chips from lower performance bins. This table comes from this reference[16] and shows the relationship between voltage, power consumption, efficiency and hashrate:

1.2 PRODUCT SPECIFICATIONS

Mode	Hashrate / TH	Power Consumption	Efficiency (W/T)	Input Voltage	Operating Temperature
High Efficiency	24.5 ± 5%	1360 ± 5%	55.5 ± 5%	12.3	-5° ~ 35°C
Normal	31.0 ± 5%	1845 ± 5%	59.5 ± 5%	13.0	-5° ~ 35°C
Turbo Mode	36.9 ± 5%	2343 ± 5%	63.5 ± 5%	13.7	-5° ~ 30°C

* The power consumption results are based on 20°C, 94% PSU Efficiency environment with the stated Input Voltage.

Notice that because turbo mode uses higher clock rates and power supply voltages, it substantially increases the power dissipation of the miner. Also notice that when in turbo mode, the maximum permissible operating temperature is reduced from 35°C (95°F) to 30°C (86°F), because lower external temperatures are required to compensate for the higher heat production in the chip.

The miner ASICs require connection to a control board in the miner that configures the ASICs, provides the input data the hashing engines work on, and collects hash results. Most miners interconnect long series daisy-chains of ASICs, where one member of the chain receives its input data originating on the control board through the previous ASICs, and passes data not meant for it down the chain toward the ASICs that follow it. Hashing results from one ASIC are passed down the chain transparently through subsequent ASICs and back to the control board. In this way, only a few wires can control, configure, supply hashing input data and collect hashing results for large numbers of ASICs.

Besides the data input and data output chain connections, ASICs have additional inputs for various clock, control, status, address, reset and test signals, and pins to provide high current core power and ground connections. The external packages of the ASIC chips are designed to collect heat generated in the silicon die inside and transport it efficiently to external surfaces of the chip so it can be removed by the cooling system.

6.2.2 Miners

High-performance miners use a large set of ASICs running in parallel to achieve high hashrates. Several subsystems of the miner support these operations. Figure 3 - Canaan 1047 Miner Front View is a photo of a typical miner of 2020 vintage, the Avalon 1047 manufactured by Canaan.[17] 20,000 miners of this basic type were hosted for SBI in the Whinstone datacenter (and another 20,000 in a datacenter in Russia). This section outlines the primary components of this type of miner, which we will divide into two primary components: the miner chassis that contains the ASICs, control boards and primary cooling system (on the left in the photo) and the external miner Power Supply Unit – PSU (on the right).

Figure 3 - Canaan 1047 Miner Front View

The miner needs a strong external enclosure called the miner chassis to protect and mechanically support the internal circuitry including miner ASIC boards and miner control boards. It is often made from bent and spot-welded sheet metal (steel or aluminum are common), with external features that allow the datacenter operator to secure it to machine racks, and internal structures to securely hold the various electronic components. The enclosure also protects the delicate circuitry inside from shock, vibration, contamination, and electrostatic discharge (even the touch of a finger on a dry day can create enough static electricity to burn out circuits), and helps direct cooling airflow.

Miners have control systems that are typically implemented on a miner control printed circuit board. These can include a supervisory processor (programmable, not ASIC) responsible for configuration and coordination of all the operations of the miner. That processor has RAM memory to store intermediate results and operational tables, and flash memory to store firmware, programs and configuration files. The control processor manages a number of interfaces, including one or more Local Area Network (LAN) ports (usually 10/100/1000Mb/s Ethernet) that the miner uses to communicate with the outside world over interconnect networks, interfaces to the miner ASIC boards and the daisy-chains of ASICs they contain, drivers for controlling the cooling system (typically providing power and control to several variable-speed fans), connections to various sensors (temperature, voltage, and current sensors, among

others), connections to the miner PSU (that can monitor and control the voltages it produces), and a user interface (at least a few status LEDs, a couple of push buttons for reset and configuration control, and in advanced miners, a touchscreen). A photo of the control board of the Avalon 1047 is shown in Figure 4 - Avalon 1047 Control Board.[18] It is located at the top of the enclosure shown in Figure 3. You can see (across the top from the left) its control buttons and LED indicators, two LAN port connectors, control and power cables to the fans, and connections to the miner PSU. The two multipin black connectors accept cables that link the control board to the two miner ASIC boards.

Figure 4 - Avalon 1047 Control Board

The heart of a miner is the miner ASIC boards. These contain the miner ASIC daisy-chains, power control circuits, interfaces to the control board, and a few support and monitoring circuits. Figure 5 is a view of one of the two miner ASIC boards from the Avalon 1046 miner (basically identical to the model 1047).[19]

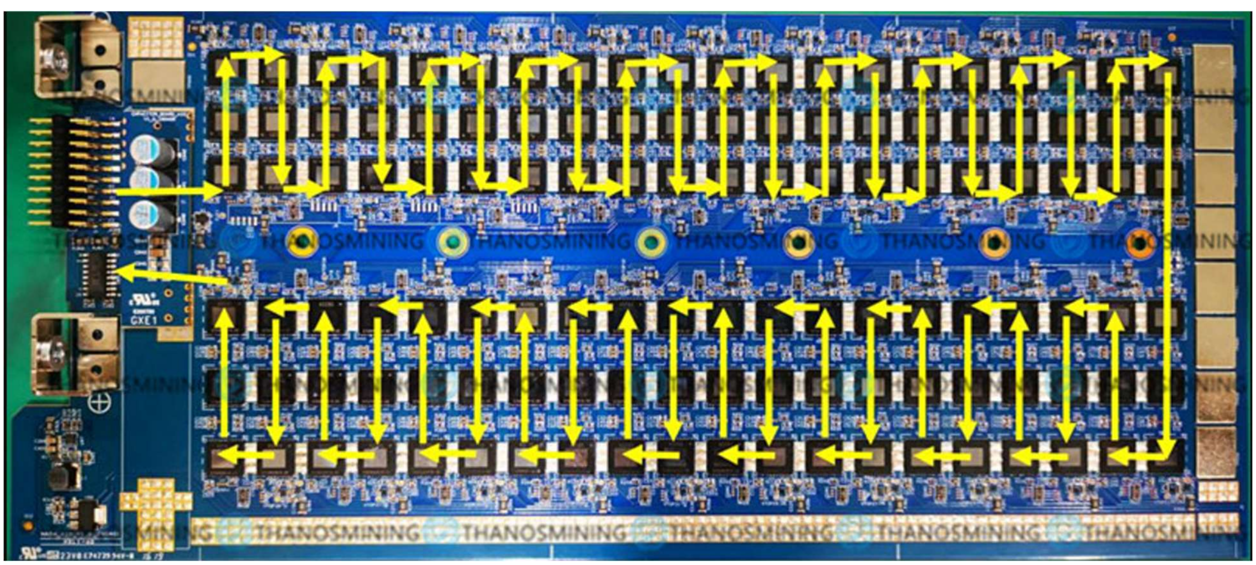

Figure 5 - Avalon 1046 Miner ASIC Board

The most prominent feature is the chain of 120 type A3205 mining ASICs. This particular picture is used as a troubleshooting guide, and shows the path the control signals take through the daisy chain in yellow arrows.

The multipin connector on the far left connects it to the control board. The two large lugs on either side of the control connector are for the primary power input (configurable to be a variable voltage of 13VDC +/- 1.5V, under software control with a current draw of about 90 Amps). The small components surrounding each miner ASIC are related to power regulation and conditioning, clock distribution, and various protection and monitoring functions. In operation this circuit board is sandwiched between six massive aluminum finned heatsinks that take the heat from the top and bottom of each ASIC package, pass it through some thermal interface material (heat sink grease or thermally conductive foam pads) to ensure good thermal contact, into the back of an aluminum extrusion, and out to an array of fins that release the heat from their surfaces into the cooling airflow. Airflow direction appears to be top to bottom in this view.

Another key subsystem of the miner chassis is cooling. Two 120mm x 120mm x 38mm primary miner fans draw about 250 cubic feet (7 cubic meters) per minute of cooling air into the enclosure, pass it over the cooling fins on the miner boards' heatsinks, and exhaust it out the back of the miner chassis. The external miner PSU has an additional two or three smaller (40mm x 40mm) fans to keep the internal components of the miner PSU cool. Although each of the 40mm fans in the miner PSU moves a small fraction of the air that the primary 120mm fans that cool the ASIC arrays in the miner chassis do, their function is vital to manage the heat generated in the high-power density components within the miner PSU. Any problems with those fans or the airflow through them can lead to system failures when stressed PSU components overheat. The actual flow achieved by the fans depend upon its RPM, and the pressure / airflow restrictions it is working against – higher pressures reduce airflow, possibly to the point where not enough air is being moved to adequately cool the electronics. These miner chassis fans typically run at 3000-4000RPM in the Canaan miner,**Error! Bookmark not defined.** but that speed can be adjusted by the control board based upon the temperature sensed by input air sensors or the die temperature sensors in each ASIC, and configuration settings as detailed in the Privileged API User Manual. The control algorithm seeks to run the miner chassis fans at a speed that will keep the die temperature of the hottest of the 240 internal ASICs below their maximum temperature rating (believed to be 85°C or 185°F). Because of the series of thermal resistances and temperature rises as the heat flows from the semiconductor die, through the ASIC package, thermal interface material, heatsink body, heatsink fins and into the airflow, the input cooling air must be below 35°C (95°F) to achieve reliable operation (per the product specifications in the Canann AvalonMiner 1066 pro User Manual in standard mode). For turbo mode, 30°C (86°F) is the input temperature limit.[20] If the input air is too hot, or if something increases the thermal resistance (airflow obstructions, failed fans, misaligned heatsinks, or dust accumulation on the heatsink fins, for example), one or more ASICs can develop hotspots, and can suffer hashrate declines, no longer be able to support higher clock rate settings, start to have errors in computation or communication, or even be permanently damaged (which could break the chain, rendering 120 ASICs useless).

The final hardware subsystem is the miner Power Supply Unit or PSU. Several variants of external PSUs are used in miners. The one on the Avalon 1047 is external (on the right side of Figure 3). Its primary input is 200-280VAC at 50/60Hz. The nominal voltage is 240V, single phase. Its primary core voltage output to the miner boards is adjustable via a control interface in the range of 11.5-14.5VDC, with a

maximum power of about 3000W. There is an auxiliary 12.0VDC output at 200W to run the control boards and miner chassis fans. The PSU functions by accepting the AC input on a standard IEC type C19 connector from a Power Distribution Unit, passing it through a power switch / circuit breaker, filtering and protecting it from AC transients and overloads, converting it to high voltage DC, and performing switching regulation on the high voltage DC bus to efficiently convert it to low voltage DC at much higher currents at precisely the commanded voltage. This low voltage, high current DC is filtered and connected to heavy busbar terminals that carry it inside the miner chassis for connection to the miner ASIC and control boards. A few smaller fans keep the components of the PSU cool. This cooling path is critical, as many of the components mounted to the heatsinks in the PSU (such as switching transistors, rectifiers and voltage regulator modules) are under considerable thermal stress, and will overheat rapidly if the cooling airflow is inadequate. A cable takes control signals and the auxiliary 12V to the control board. These PSUs tend to have very high efficiency, meaning that 95+% of the input power is delivered to the miner chassis circuitry, leaving a few percent as heat inside the PSU (but that is still on the order of 100 Watts of waste heat will accumulate inside the PSUs if not continuously removed). The nominal power draw of each Avalon 10xx series miner is 2361 Watts, which is about twice the average power used by a single American household.

Miners also have a significant amount of firmware that is run on the control board and used to configure the ASICs. The firmware accepts commands and input data from the network ports, manages the configuration of the miner ASICs, fans and PSU, reports status and returns results of the mining to the miner pool. The miner firmware receives frequent updates to correct bugs, add new features, or make modifications to the miner algorithms to improve efficiency. Best datacenter practices call for the limited deployment testing of new firmware releases on a few miners first, and if it is acceptable, rapid deployment of the firmware update to the entire fleet of miners.

6.2.3 Interconnect Networks

Miners need network connections to function. These are typically in the form of Ethernet copper cables between the miners and networking equipment. Miners usually don't use much network bandwidth during operation, so 10Mb/s or 100Mb/s data rates are sufficient. Some advanced miners use gigabit ethernet. These connections carry the configuration instructions for the miners, their status reports and sensor readings, input data that the hashing functions are to work with, software updates, status reports and output data from the hashing functions (including information about any newly mined cryptocurrency). Obviously, high performance, reliable network connections are vital to a successful miner installation.

The ethernet cables from a set of miners are collected at an Ethernet switch often located within their equipment rack (called a Top of Rack or ToR switch). Its function is to accept all the connections to a group of miners (48 ethernet ports between the ToR switch and miners is a common size) and combine them into one or a few upstream connections. Upstream connections are usually faster (because they carry the combined traffic of dozens of miners), running at 1 or 10Gb/s. Sometimes the upstream connections are metallic ethernet cables (if the length of the upstream cable is less than the 100-meter maximum copper cable length allowed by the Ethernet standards), and other times it is a fiber optical connection (that could go 2000 meters or longer, and can be much faster). Upstream cables from the ToR switches in many racks of equipment are routed to the next layer of interconnect, often called the leaf switch. These concentrate the traffic from several thousand miners onto a high-capacity upstream

link that can go directly to the internet service provider, or (in very large datacenters) to a top-level switch called the spine switch.

Ultimately, the traffic from an entire datacenter full of miners is passed onto a few fiber optical transmission lines that exit the datacenter and enter the long-haul optical internet backbone, for routing worldwide. Many datacenters use two or more separate cables to carry their external traffic, so if one cable is accidentally cut or has some other failure, other cables can accept the load, and all the equipment in the datacenter can still reach the internet. The internet service provider contracted by the datacenter accepts these long-haul facilities and connects the fiber cables to a regional routing center called an internet point of presence, where large-scale backbone routers determine where the traffic from the miners must go, and send it cross-country on appropriate network backbone or undersea cables. Often, the destination of the miner internet traffic is a server run by a mining pool provider that manages their configurations, monitors their status, dispatches mining work for each miner, and collects their hashing results and any newly discovered bitcoins.

6.2.4 Mining Pools

Large fleets of miners are managed in mining pools. These fleets could span multiple datacenters across the globe, and consist of thousands or even millions of individual miners. They coordinate the input data to each miner in the fleet to make sure they are all working on useful computational problems, and as hashing is successful, they collect any mined cryptocurrency and make it available to the market. There are usually sharing arrangements, where all miners in the pool share the rewards generated by the entire pool. This reduces the impact of some set of miners having an “unlucky streak” where they discover no cryptocurrency for some extended time.

Pools also monitor the performance of individual miners and entire datacenters, and can adjust miner settings to try to optimize the collective hashrate and electrical consumption. They can also alert maintenance crews in the datacenter if certain miners are having problems (common problems include overheating, incorrect fan speed, network connections problems, PSU failures, cybersecurity threats, etc.). As new software updates are made available for the miners, the pool control software can update the entire fleet.

6.2.5 Power Management / Demand Response / Real Time Markets

As mentioned previously, there is a tradeoff between miner hashrate and the power each miner draws. One additional input to this tradeoff is the real-time market price of electricity. The power purchase agreements negotiated between datacenters and their electricity suppliers specify a certain electric rate (cents per kilowatt-hour) and the maximum number of megawatts the datacenter is permitted to draw. Occasionally (for example, on summer afternoons when air conditioners are running, or cold nights when electric heaters are on), the electrical demand on the grid is larger than its generation and transmission capacity. In these instances, it is possible for the datacenter to reduce its consumption to help prevent overloads and blackouts for the millions of electrical customers on that segment of the grid.

Some power purchase agreements require datacenters to shed some load (especially those with auxiliary Diesel generators that can be started with ten-minute notice) if informed that a grid overload is imminent in a process called demand response. Other power purchase agreements use a real-time marketplace, where the spot price of electric power can be much higher than the negotiated cents per

KW during grid overloads, and datacenter operators are invited to "sell back" some or all of their capacity at a much higher temporary rate. Calculations are done by the miner pool or other management organization to determine if this sale of electric capacity is more valuable than the bitcoin that could be mined with that power (often it is), and some miners can be switched off, or the clock rates and voltage settings of the miner ASICs can be reduced to greatly cut energy use (while still mining some crypto). In either scenario, once the electric grid demand peak has passed, the datacenter quickly returns to its normal configuration and mines at full speed.

6.2.6 Supervisory Functions
Certain supervisory and monitoring functions are needed for safe and efficient crypto datacenter operation. Power input must be monitored to prevent overloads and stay withing the limits of the power purchase agreements. The environment of the datacenter (especially input air temperature to the miners) must be carefully controlled to ensure no miners overheat. Miners must be periodically monitored to detect any component failures, networking problems or out of spec status reports, and timely repairs must be made. The best datacenters are proactive in continuously monitoring these conditions, and rapidly respond (often within minutes) to make adjustments or repairs if something needs attention. Other datacenters only install the legally-mandated sensors, and have very limited data about the more sophisticated aspects of the datacenter environment.

6.2.7 Firmware / Software
The manufacturers of the miners are constantly optimizing the firmware that runs the control boards, and the configurations for the mining ASICs. Frequently (typically once every couple of months) a new release of software becomes available. The datacenter owner and mining pool administrators can decide when they have enough trust in the new version of software to download and enable it in all miners. Occasionally one chooses to try the new code out on a few machines, but wait a few weeks before updating the entire fleet in case problems are discovered. Other times, the update is urgent (for example because of a critical emerging cybersecurity threat or safety concern), and all miners are updated immediately.

6.2.8 Miner Suppliers / Product Families
There are many suppliers of various types of crypto miners. Some are software programs that anyone can run if they have the required CPU, GPU or gaming system. Some are specialized programs that run on specialized programmable hardware, for example using Field Programmable Gate Arrays. Still other do most of the work on ASICs that are optimized for a specific set of algorithms. A single ASIC-based miner has thousands of times the hashing capacity of a high-performance desktop computer or gaming system.

Most suppliers offer multiple kinds of miners, to suit the scale, scope, energy requirements and budgets of many different potential customers. Various reports and benchmarks such as this reference[21] compare the performance of miners, with the most important figure of merit being Joules of energy per terahash. This tends to drive the rest of the total cost of ownership computations.

6.2.9 Large-scale Crypto Mining Economics
The economics of crypto mining are complex. Some of the factors that are important are the purchase or lease price of the miners, the various dynamic difficulty factors for the crypto mining algorithm, the performance and energy efficiency of the miners, cost per KWh of electricity, the efficiency and cost of

the datacenter infrastructure (especially cooling system), installation, operation and maintenance costs, the expected and actual reliability rates of the miners, the terms of the miner pool agreement, the anticipated sale price of any cryptocurrency that is mined, and the residual / scrap value of the miners and their components. These economics tend to favor large scale mining farms installed in efficient, low-cost datacenters in regions with low power costs, low PUEs, and moderate climates (to reduce cooling costs). The most suitable miners tend to have large chains of modern ASICs (several hundred), and efficient power supplies.

6.3 SBI Mining Network Architecture

In Spring of 2019, SBI Crypto ordered two networks of 20,000 each Avalon 104x series miners made by Canaan. One set was installed in the Whinstone datacenter in Rockdale, Texas, USA starting in the November of 2019, and the other was installed in late 2020 in the Bitriver facility in Bratsk Irkutsk Oblast in East Russia. Both of these facilities were chosen because of their access to large amounts of low-cost electric power, efficiency, and low hosting fees. The bulk of the analysis in this report will focus on the Whinstone Rockdale, TX facility, with occasional references to the Bitriver Russia facility for comparison purposes. This reference is a video overview of the Whinstone Rockdale datacenter:[22]
https://www.wired.com/video/watch/wired-news-and-science-inside-the-largest-bitcoin-mine-in-the-us

6.3.1 Overall Network

SBI has developed an architecture for a large-scale crypto mining network. It uses 40,000 ASIC-based crypto miners of the Avalon 104X family, half installed in Rockdale, TX and half in Russia. The miners are configured as a miner pool, and any cryptocurrency mined is property of SBI. Extensive economic analysis[37] was performed before the miners and datacenters were selected, based upon anticipated rates of return given the price trends of cryptocurrencies and the expected hosting fees / power costs and achievable hashrates. Three types of cryptocurrencies can be mined by this network: Bitcoin, BTC and BSV. Bitcoin is believed to be the strongest contributor to the economic success of the network, and the other two cryptocurrencies are supplemental / hedges.

6.3.2 Miner Types / Models / Suppliers / Clusters

Four different models of Canaan Avalon miners are used in the Rockdale datacenter. A status report[23] on 6/26/2021 that queried the entire network yielded this complement of active miners:

Miner Type	Number of active miners reporting
1044	1
1045	4730
1046	2731
1047	5598
Total:	**13060**

Note that only 13060 active miners reported their status. This is approximately 65% of the 20,000 installed miners, because by this time about 1/3 of the miner fleet had failed at this point in the deployment timeline. All four models of the Canaan Avalon 10XX series are similar – the differences relate to the maximum performance in the turbo mode caused by manufacturing variations / binning of the ASIC chips within them.

6.3.3 Network Functional Partitioning

The highest level of the network is the pool, which includes the Rockdale, TX datacenter (20,00 miners installed), the Russia datacenter (20,000 miners installed, about six months behind the Rockdale schedule), and some other miners in various smaller and test installations. This pool dispatches workloads to the miners and collects their results (including the crypto keys to any bitcoins they have mined). Network facilities including long-distance fiber optical cables and backbone routers connect the pool to the datacenters. At the high level of each datacenter, a communications infrastructure connects the external internet traffic to a large number of ToR switches. In Rockdale, each ToR switch supports 48 miners, so 417 are required for the entire installation of 20,000 miners. Simple ethernet cables connect the ToR switches to individual miners.

6.4 Deployment of SBI Miner Clusters at Whinstone Datacenter

This section describes the physical, electrical and cooling infrastructure of the Rockdale datacenter. Understanding the implementation of these systems is valuable for the analysis in subsequent sections.

Whinstone's Rockdale TX datacenter (now part of Riot Platforms) is part of a multi-building development on land that was formerly part of an industrial campus dominated by an Alcoa aluminum smelting plant. That plant was in operation 1952-2008 and used massive amounts of electricity generated by an adjacent coal-fired power plant to electrically refine up to 1.67 million pounds of aluminum per day.[24] The electrical grid infrastructure supporting the smelting plant is still in place but was lightly loaded before the datacenter was constructed, and the heavy industry friendly political climate in the region makes the site attractive for datacenters.

6.4.1 Site layout

Figure 6 -Whinstone Rockdale, TX Datacenter Aerial View shows the datacenter and some of its surrounding infrastructure.[25] The Sandow Switching Station is a power grid switching center that accepts input from three high voltage transmission lines and is capable of providing around 900 megawatts to the datacenter via an overhead 138,000 volt transmission line.[26] A private power substation owned by Whinstone extends across the south ends of the buildings. Building B of the datacenter is capable of providing 75 megawatts of power capacity. The SBI miners use approximately the southern ⅔ of Building B (indicated by the red dotted rectangle). The cooling system of Building B (constructed, although apparently not operational) has two wet curtain walls that evaporate water to provide cooling air to the miners. No mechanical cooling or supplementary fans to boost airflow are installed in Building B.

Whinstone Rockdale, TX Datacenter Aerial View

Figure 6 -Whinstone Rockdale, TX Datacenter Aerial View

6.4.2 Architectural Design of Building B

Construction drawings of Building B are available in this reference.[27] This building is approximately 1050 feet long, 60 feet wide and 32 feet high (320 x 18 x 10 meters). This section includes a selection of the construction drawings illustrating key features of the building

Building B Construction Drawings, Orthographic View

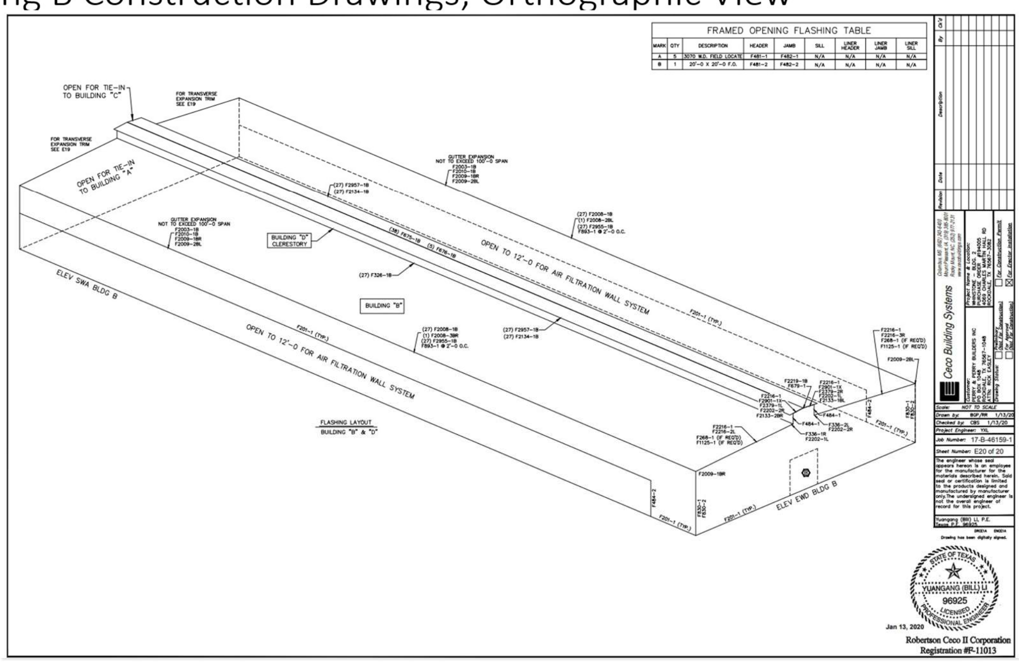

Figure 7 - Building B Orthographic View

Building B Construction Drawings, Endwall Elevation

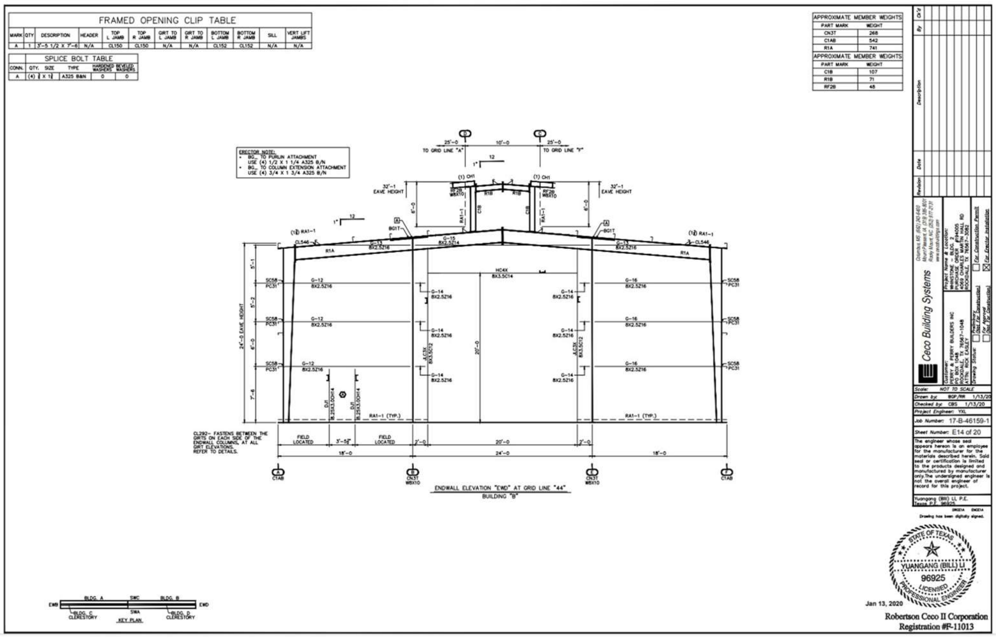

Figure 8 - Building B Endwall View

Building B Construction Drawings, Front Elevation

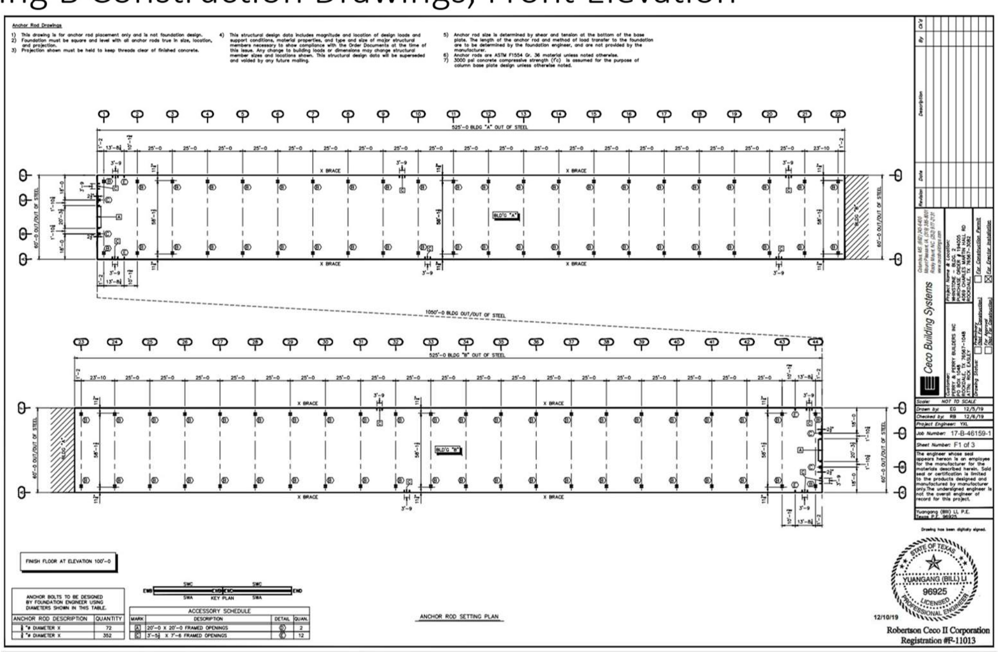

Figure 9- Building B, Front Elevation

Figure 7 - Building B Orthographic View is a good orientation view of the building. It is basically a long steel structure similar to the buildings used for warehouses or large-scale livestock operations capable of housing and providing some level of cooling for up to 75 megawatts of datacenter equipment. The lower 12 feet (3.6m) of the front and back walls are open to facilitate the installation of evaporative cooling panels, but the evaporative pads are only 10 feet (3m) high, consisting of two stacked 5-foot (1.5m) panels. Overhead doors on the two ends and several smaller doors in the front and back elevations facilitate access.

Figure 8 - Building B Endwall View shows some of the important features. Most important of these is the clearstory roof intended to allow the flow of hot exhaust air out of the building. Clearstory is an architectural term for a set of vertical walls placed on a roof to admit light or provide ventilation. The clearstory feature is approximately 10 (3m) feet wide and rises six feet (1.8m) above the main roof of the building. Both of the approximately 1050 foot (320m) long by 6-foot (1.8m) high sides of the clearstory consist of exhaust air louvers approximately 4' high intended to permit passage of exhaust air while keeping out weather and foreign objects.

Figure 9- Building B, Front Elevation shows two halves of the long front wall of the building. A number of the structural elements, including major steel support members on 25-foot (7.6m) centers are visible.

Overall, the building is structurally adequate, but certain design decisions evident on these drawings have compromised the cooling and internal environment of the datacenter.

6.4.3 Power Infrastructure for Building B

Figure 10 - Whinstone Datacenter Power Architecture is a simplified depiction of the power infrastructure that supplies Building B (as shown in a view from the end of the building). Power arrives from the Texas Grid on three cross-country transmission lines called Alcoa Tie 1, Alcoa Tie 2 and Alcoa Tie 3. These feed a matrix of circuit breakers in the Sandow Switching Station owned by Oncor Corporation that protect and direct energy between various sources and destinations.[26] The nominal voltage in this switching station is 138,000 volts, 60 Hz, three phase "Y" connected. Circuit breakers in the Sandow Switching Station can connect the datacenter to one of two power switching buses that can be configured to accept energy from various combinations of the three incoming tie lines, and distribute it to several loads. Approximately 2000' of overhead cables cross Charles Martin Hall Rd and the Whinstone datacenter fence, pass over about seven towers, and enter a private substation owned by Whinstone. Large transformers convert the 138,000 volts to 13,800 volts that is safer to distribute underground. The transformer dedicated to Building B appears to be in the 100MW rating range. Underground cables distribute the 13,800 volts to a series of 30 2.5MW step-down transformers surrounding the perimeter of Building B. These transformers step down the voltage to the 240 volts required by the equipment inside (the actual output voltage on each of the three phases from the transformer is greater, but 240V is the nominal phase-phase voltage used by the miners). This power distribution infrastructure is designed to use higher voltages for longer distance power lines, because that minimizes the resistive power loss, and lower voltages in areas where humans or earth may come in contact with them for safety reasons.

The output of each step-down transformer feeds through an outdoor switchgear cabinet that protects, controls and measures the power. The switchgear is manufactured by Eaton, and described in this reference.[28] Power from the switchgear is routed through short underground ducts to about three

breaker panels distributed evenly in the cold aisles inside Building B, manufactured by Westinghouse, and described in this reference.[29] The Building B plan calls for 94 of these breaker panels.[30] The breaker panels have circuit breakers to divide and protect the power, and distribute via heavy cables supported by overhead cable racks it to the Power Distribution Units (PDUs) on the equipment racks. Each breaker panel supports about seven racks of equipment (called a "Wall" by the Whinstone technicians), each rack with four ~30KW PDUs (depicted as small red rectangles on the server racks), for a total capacity per breaker panel of about 800KW. Each PDU has twelve ~10 amp / 240VAC power outputs that connect to twelve of the miners on the rack with short whip cables. The 20,000 SBI miners use the full capacity of about twenty of the 2.5MW step-down transformers (and associated switchgear, breaker panels and PDUs), for a design power rating of 50MW (two thirds of the total capacity of Building B).

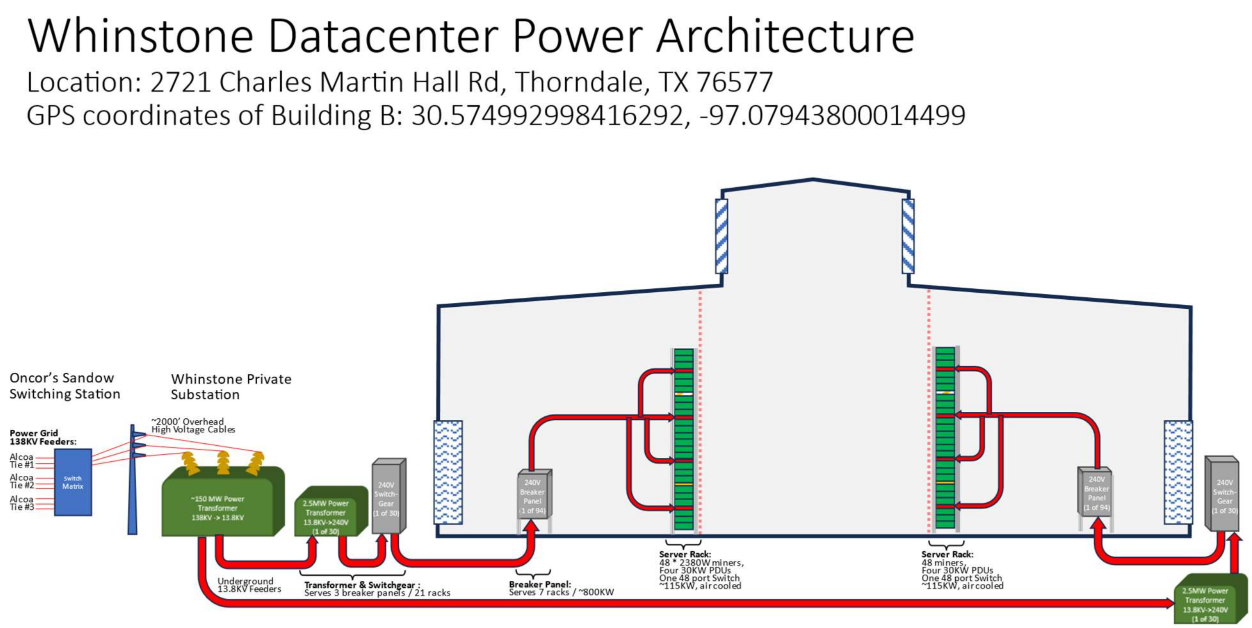

Figure 10 - Whinstone Datacenter Power Architecture

6.4.4 Cooling Infrastructure for Building B

Whinstone Building B uses no mechanical refrigeration as would commonly be found in many datacenters. Instead, as shown in Figure 11 - Whinstone Datacenter Cooling Architecture, which is an end view of Building B, it draws outdoor air through the sidewalls of the building into two cold aisles, it passes through the racks of equipment, and into a shared hot aisle running down the center of the building, where it is intended to exhaust to outdoors through vents in the clearstory roof. The miner chassis and PSU cooling fans were the only source of power to drive the air through the building, but as detailed in subsequent analysis, do not have sufficient capability to do so. Sequestration walls made of rigid foil-faced foam insulation boards are intended to seal the back of the miners to the hot aisle to prevent recirculation of hot exhaust air from the hot aisle back into the cold aisle and into the miners' air intakes, but as outlined in subsequent analysis, have significant installation and maintenance problems.

This paragraph describes the concept of the cooling scheme for Building B as designed, although it was apparently not operated as described during the installation timeframe of the SBI miners. This cooling scheme may be adequate if the outdoor temperature is below about 35°C (95°F) if the miners are in normal mode, or 30°C (86°F) if they are in turbo mode. If the outdoor temperature is hotter than that (which it often is in Texas), supplementary cooling is supposed to be provided through the wet curtain wall system in order to maintain inlet temperature below the 29.5°C (81.5°F) maximum specified in the hosting agreement.[2] The wet curtain wall consists of approximately 2000 5' high by 8" thick by approximately 2' wide (approximately 152 x 20 x 60cm) panels of corrugated porous cardboard-like material, stacked two high, manufactured by Munters[31]. Water is to saturate these panels, and as the outdoor air passes through them and the water they contain evaporates, a process called adiabatic cooling can reduce the air temperature by 10°C (18°F) or more as it enters the cold aisle under favorable conditions with low outdoor relative humidity. Spray heads are to pump 1000 gallons (3785 liters) per minute of fresh water to the top of the evaporation pads. The water is to zig-zag down through the pads by gravity, making the corrugated surfaces damp. Air passes through the gaps between the corrugated surfaces, evaporating some of the water and cooling the passing air in the process. Any water that is not evaporated would fall into a gutter below the panels, where it would be collected and directed to a set of eight 3000-gallon (11,300 liter) underground tanks surrounding Building B. Pumps in the tanks would return the water to the spray heads. At full cooling capacity, Building B could evaporate 400 gallons (1500 liters) of water per minute (over half a million gallons or two million liters per day).[32] To compensate for evaporation losses, makeup water could be drawn from Alcoa Lake, through a pumphouse and to refill valves in the eight tanks.

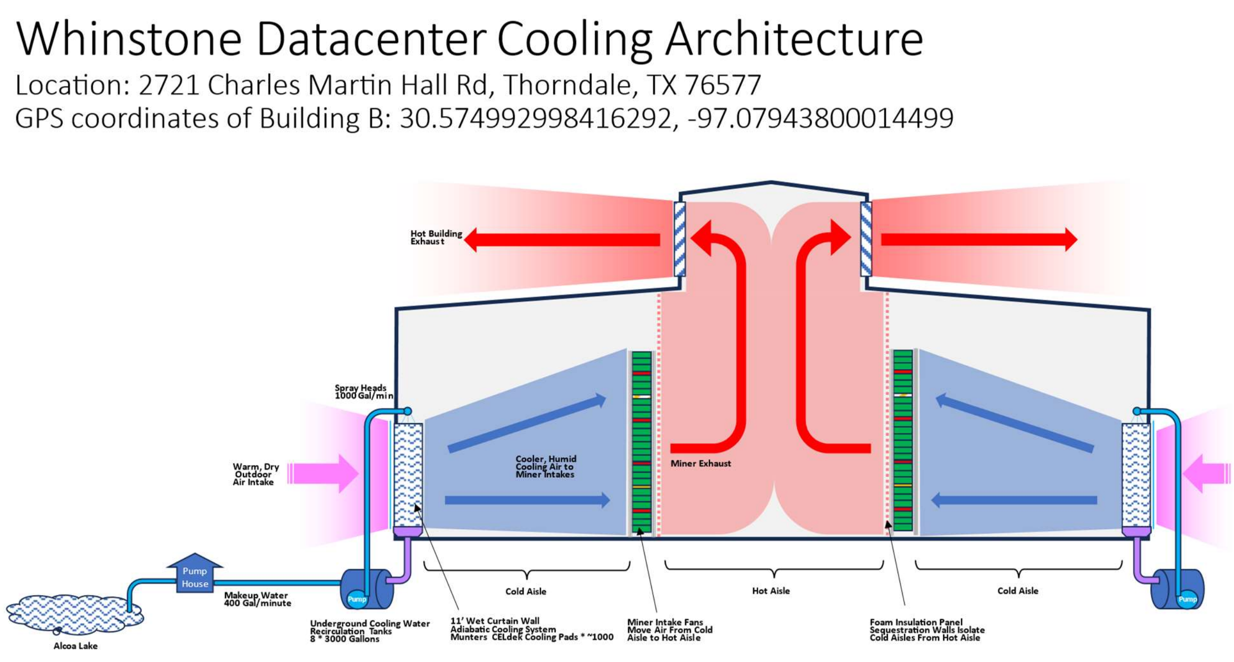

Figure 11 - Whinstone Datacenter Cooling Architecture

6.4.5 Rack-level Architecture

The 20000 SBI miners occupy about 417 equipment racks (of the approximately 644 racks of this type that could be supported in the entire building), with 48 miners per rack. These racks were designed, constructed and installed by Whinstone. They are approximately three feet wide, two feet deep and 20 feet tall (approximately 90 x 60 x 600 cm). Each rack integrates mechanical support, power distribution, networking and cooling features for all the miners it holds. These racks are grouped into "walls" of seven adjacent racks that share an overhead cable rack to the power breaker panel on the other side of the cold aisle. Installation, control, update and maintenance operations in the datacenter are often organized by these "walls" of seven racks (a total of 336 miners, or about 800KW per wall). About 59 walls make up the complete installation.

As shown in Figure 12 – Miner Rack Arrangement, each rack consists of 30 shelves, 24 of which are spaced about 9" (23 cm) apart, with the remaining six spaced about 5" (13 cm) apart. Four upright columns are securely bolted to the floor and the shelves. The 24 wider shelves each accept two of the Canaan Avalon 104X miners, rotated 90° onto their left side, with the miner chassis on the bottom and the miner PSU on top. Four of the six narrower shelves accept 12 outlet, ~30KW power distribution units. An additional narrow shelf accepts a 48 downstream port / one upstream port ToR ethernet switch. The final narrow shelf is unused in most racks, but could be used for a second Ethernet switch if needed for reliability or additional network bandwidth to the rack, or for monitoring equipment. For engineering, installation and maintenance simplicity, the racks can be divided into a stack of four clusters of twelve miners each, consisting of three lower miner shelves, a PDU shelf in the middle, and three upper miner shelves.

Data cables follow a star topology, with 48 standard Ethernet jumper cables (shown in light blue of Figure 12 – believed to be category 3 type cables) connecting between one port on each of the 48 miners and the 48 downstream ports on the switch.[33] A single ethernet cable (shown in darker blue) connects the switch to the networking room, and thence through datacenter-level routers to the internet backbone. The data cables are neatly routed and cable tied to the leftmost upright column.

Two types of power cables are used in the miner rack. Whip cables (shown in black) connect the power connectors on twelve miner PSUs to the closest PDU. These whip cables are neatly routed and cable tied to the rightmost column. The second type of cable is four heavy-gauge feeder cables (thicker black cables with a white stripe) that connect each PDU to a breaker panel about 20' (6 meters) away on the other side of the cold aisle. These cables are routed along the back side of the right upright column, and onto an overhead cable rack that is approximately ten feet (3m) above the floor slab and terminates above a breaker panel[34]. Each cable rack actually supports the heavy feeder cables from a wall of seven equipment racks that are routed horizontally behind the PDUs (7*4=28 heavy feeders per overhead cable rack / breaker panel) to operate a wall full of routers.

Cooling air is also managed by the equipment racks. Cooling air from outdoors is drawn through the louvers, bug screens and evaporative media the cold aisle, across the shelf, and into the intake fans of the miners. Each miner chassis has two 120 mm (4.2") primary cooling fans to cool its boards of mining ASICSs, and two (or sometimes three for certain models of PSUs) smaller fans to cool its PSU. The full rack of 48 miners has 192 or more fans intended to draw air from the cold aisle into the front intakes of the miners' chassis and their PSUs. On the opposite side of the racks, the hot miner exhaust ports are aligned with the back edge of the shelves, and blow through tight-fitting apertures in the sequestration

wall into the hot aisle. Various airflow seals on the rear surface of the equipment rack (often using a combination of foam board and duct tape) attempt to direct and confine the exhaust air streams from the miners and PSUs into the hot aisle. It is important to minimize the gaps and leakage paths between the rear of the racks / hot aisle and the miner intakes / cold aisle to ensure hot exhaust does not recirculate back into the cold aisle (although in practice, many significant gaps were observed). This is because any recirculation of hot aisle air would pre-heat the intake air into nearby miners to unacceptably hot temperatures. If a miner or one of its fans, PSUs or control boards fails, air from the hot could be pushed backwards through the non-operating fans in the failed miner and contaminate the inlet air to nearby miners.

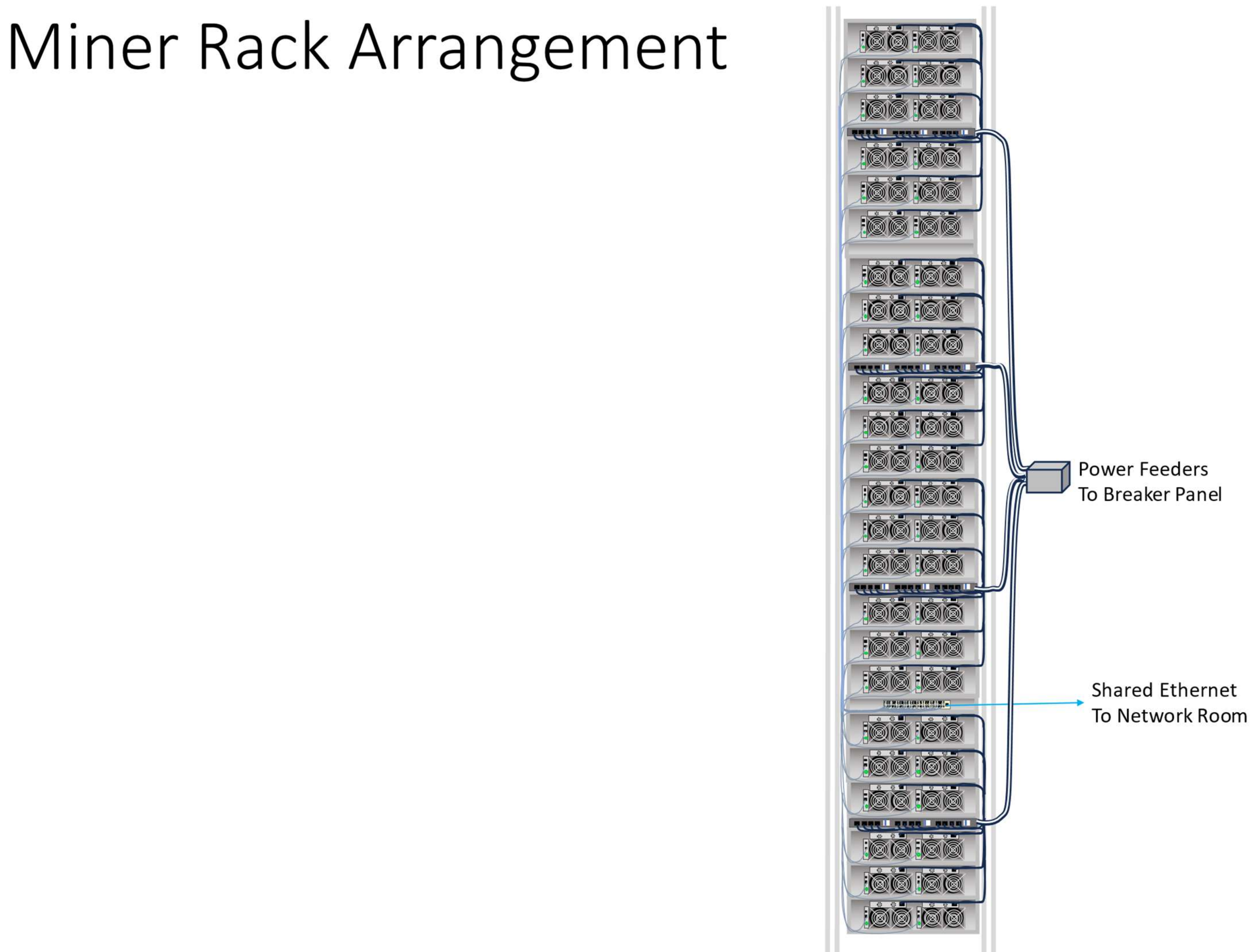

Figure 12 – Miner Rack Arrangement

6.5 Miner Installation

The 20,000 miners ordered by SBI[35] from Canaan were delivered in late 2019. 25 miners were installed November 24-26 2019 as a test installation, but delays in finishing Building B of Whinstone's datacenter and securing the required power and water rights prevented the completion of the installation of all 20,000 miners until August 12, 2020. Whinstone's promised schedule of the datacenter being ready for full installation of all miners was December 2019, as shown on page 16 of their pitch deck.[36] They ran (with many problems, to be described below) until the hosting contract with Whinstone was terminated on June 28, 2021, and they were removed and crated for shipment by August 2021. Figure 13 - Miner Installation Log shows the reported installation rate of the miners in Rockdale as reported in this reference.[37]

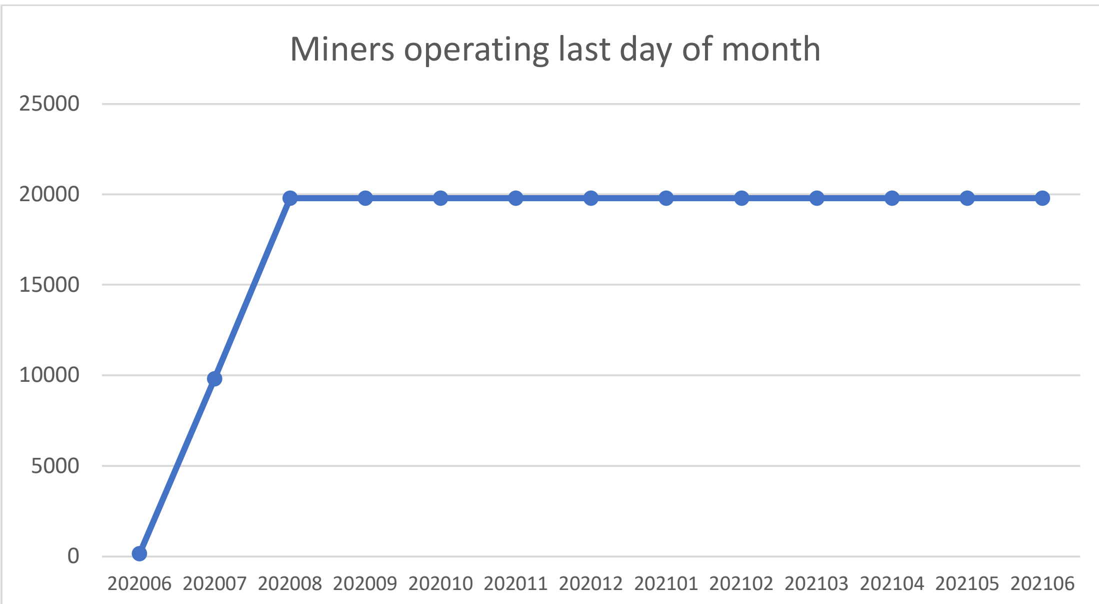

Figure 13 - Miner Installation Log

The number of active miners on the first of each month is tracked in a spreadsheet.[37] Notice that the total fleet of miners installed is 20000, and given 13060 responded to the 6/16/2021 ping request,[38] almost 7000 miners (35% of the fleet) had failed, were misconfigured or somehow had disconnected from the network. This is not reflected in the above graph. If they can't answer the ping, they can't communicate with the pool, and therefore can't mine. Detailed statistics of the actual number of miners actively mining for at least some portions of the installation interval are shown in section 6.7.1.

6.5.1 Timeline of Events

It is important to understand the timeline of events associated with the deployment of the 20000 SBI miners in the Whinstone Rockdale datacenter. Figure 14 - Operational Timeline describes the approximate timeline for various key events in the deployment. Most of the individual events shown in this summary will be described in greater detail below.

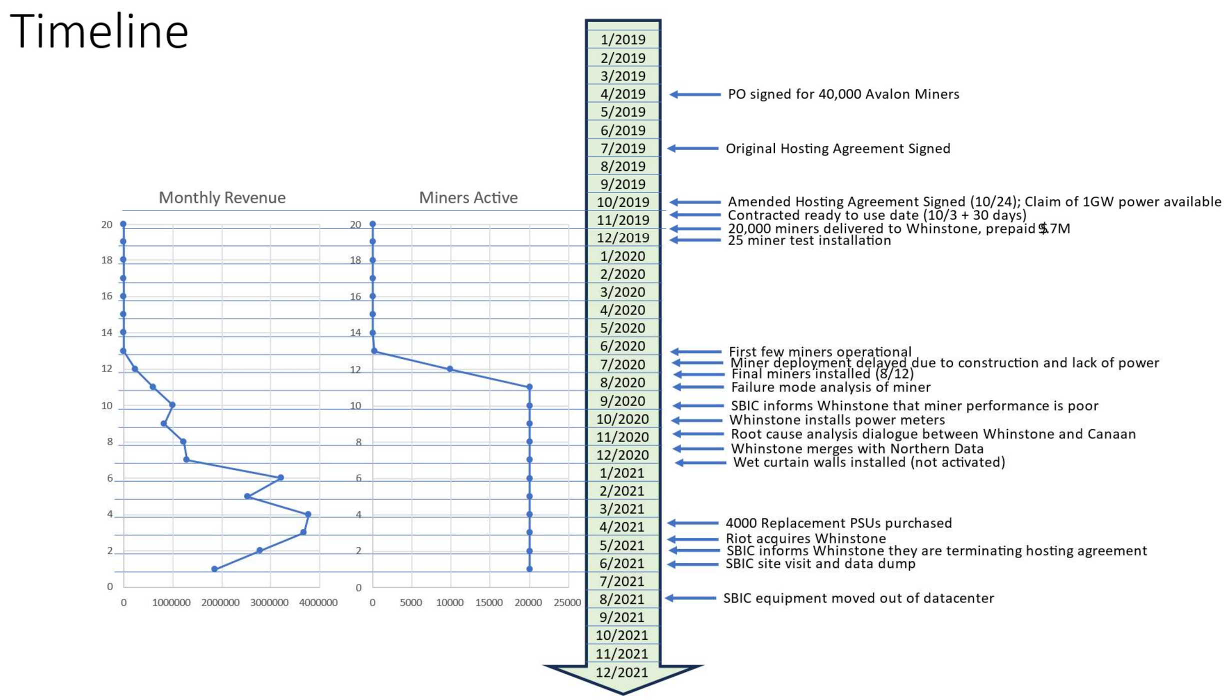

Figure 14 - Operational Timeline

6.5.2 Original Contract and Modifications

Preliminary terms between SBI and Whinstone from September 2019 are in this reference.[39] The signed agreement appears here.[40] SBI provided significant up-front investment to enable Whinstone to complete the build-out of the datacenter, which was to be paid back in monthly reductions to hosting fees. There is a clear set of contracted expectations between SBI and Whinstone about the basic infrastructure they would maintain in the datacenter, and as will be clearly shown in following sections, many of these expectations were not met.

6.5.3 Expected Datacenter Environment

The specifications for the Canaan Avalon miners and the hosting agreement clearly specify the environmental requirements for the datacenter. A key requirement is the incoming cooling air temperature at the input fan for the miners. The Avalon Miner 1066pro spec sheet shows an allowable temperature range of -5°C (28°F) to +35°C (95°F) (30°C / 86°F max for turbo mode) measured at the miner's air input.[41] The Avalon 104X series of miners used in this datacenter have nearly identical requirements for cooling air.

Section 2.2.13 of the hosting agreement [40] (Signed 10/24/2019) specifies "Air intake temperature into the Customer's miners is not greater than twenty-nine (29) degrees ." Similarly, Hosting agreement SBIC0003894,[42] clause 4.6.7, it states temps not to exceed 29.5C. If Whinstone succeeded in maintaining maximum cold aisle temperature of 29.5°C (85.1°F), the miners should have seen air intake temperatures of well under their 35°C (95°F) maximum ratings (and just below the 30°C (86°F) rating in turbo mode). As we will see, the committed maximum temperature was routinely exceeded.

6.5.4 Expected Failure Rates

Miners of this type, if correctly manufactured using engineer-specified materials and assembly processes, and operated inside of their specified ranges for temperature, humidity, dust, shock, vibration, and input power quality should have an annualized failure rate of less than 1% per year, or about 17 miners per average month in a fleet of 20,000 active miners. Once a miner fails, it is the datacenter's responsibility to detect, isolate and repair the failed equipment (per the "Remote Hands" clause of the hosting agreement).[2] If it takes them a month on the average to repair a miner and return it to service, at least 19,983 miners, on average, should be active at any given time.

6.5.5 Expected Miner Productivity

The expected productivity is the product of the average number of miners that are up and active multiplied by the average hashrate of each miner, corrected by factors related to the difficulty set by the bitcoin algorithm. Figure 15 - Measured Daily Average Hashrate is the actual hashrate achieved by the miner fleet, based upon telemetry recorded as its results were returned to the miner pool.[43] There were several multi-day intervals of very low productivity, probably caused by a combination of power / networking failures, weather events, sale of some of the allocated energy back to the real-time power market, and operational problems in the datacenter. The most important observation is the trendline downward slope as miners fail and are not returned to service. This downward trend started in late September 2020 and continued until late June 2021 (when the miners were removed). About 48% of the hashrate capacity was lost during this nine-month interval, implying about 5% or 1000 miners were failing and not being repaired per month. If the datacenter was working as stipulated in the hosting agreement, the expected hashrate for this fleet of 20,000 Canaan 104X miners is 703,000 terahashes (which would be just above the top gridline). The fleet never achieved hashrates above 70% of this expectation, and at the end of the deployment was under 40%. This is the primary cause of the economic losses SBI experienced.

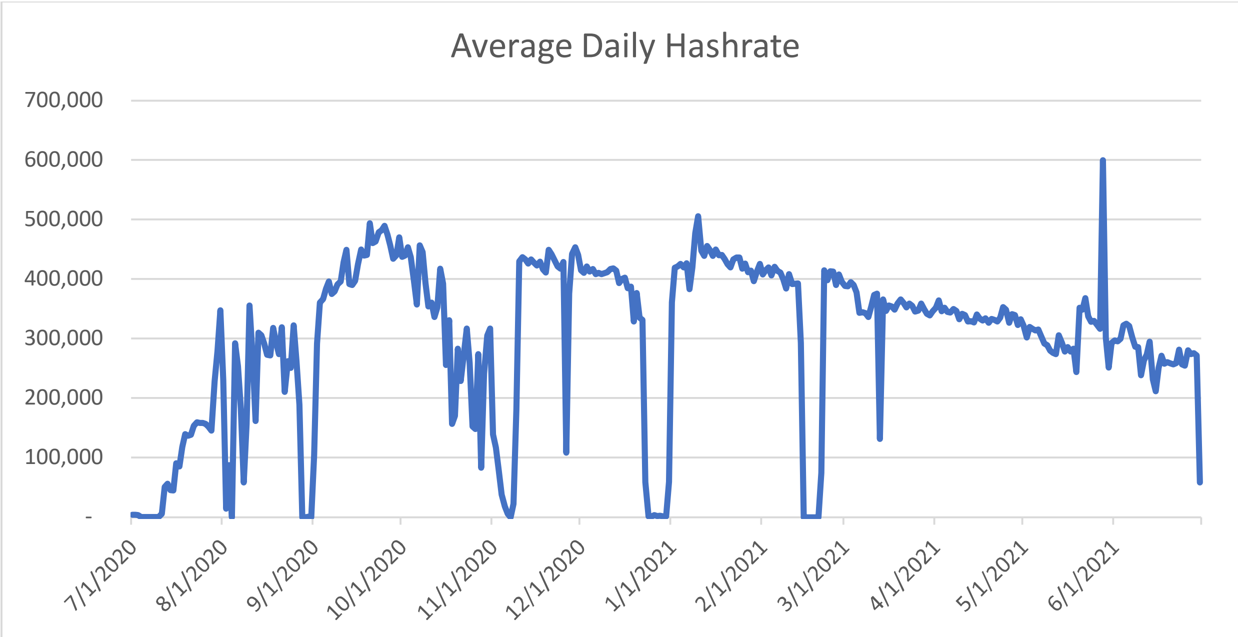

Figure 15 - Measured Daily Average Hashrate

Figure 16 - Actual vs. Anticipated Mining Revenue shows the difference between the original model[44] (assuming full performance from each miner and a 1% failure rate) and the productivity actually achieved[43] by the Rockdale datacenter.

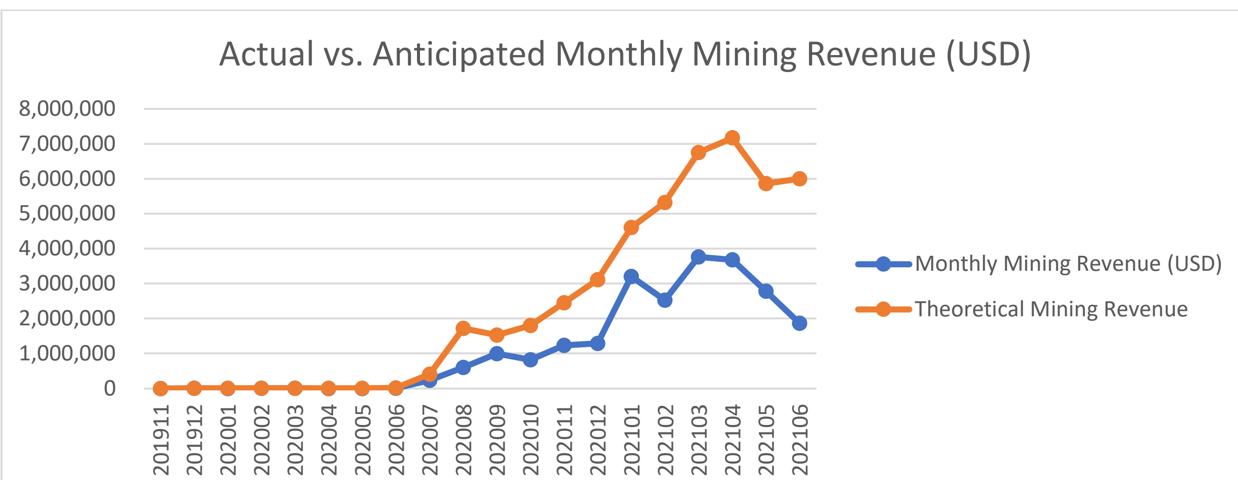

Figure 16 - Actual vs. Anticipated Mining Revenue

The area under the red curve was the expectation that SBI had for lifecycle revenue from this facility, the area under the blue curve is actual revenue. The significant differences between these areas are an important illustration of SBI's losses.

6.5.6 Observed Performance

The miners installed in Whinstone's Rockdale facility did not perform to expectations on several key performance metrics:

- The miner fleet did not achieve the 99% availability target. In June 2021, the rate was around 65%.
- The input temperature to the miners was consistently higher than the contracted 29°C (84°F). Precise measurements of actual intake temperatures are not available, but one can infer much higher intake temperature on many days based upon climate records and the fact that the wet curtain wall was not operational during the deployment timeframe, so there were no means to lower the outdoor temperature before it reached the miner intakes. Also, there is testimony from Whinstone personnel that indicates the heat wall did not prevent recirculation of hot air into the cold aisle, as well as testimony that suggests that hot air also was allowed to recirculate through nonfunctioning miners left on the rack.[45]
- Other environmental best practices related to air filters, dust exclusion, and protection from corrosion and insects that were required by the Hosting Agreement were not adhered to.
- The modeled miner revenue was underachieved by approximately a factor of two over the life of the installation as shown in Figure 16 - Actual vs. Anticipated Mining Revenue.

6.6 Problems / Concerns with SBI Installation in Whinstone Rockdale, Texas Datacenter

6.6.1 Initial Symptoms

There are several instances of Whinstone not conforming to the requirements of the hosting agreement and / or industry best practices. The first symptoms were delays in the installation, powering up and commissioning of the miners. The Ready For Use (RFU) date specified in the hosting agreement[2] is Oct. 31, 2019 for the first 5MW, and all 50MW available by Dec. 15, 2019. The first five miners were actually installed on 11/24/2019,[44] with ten additional miners on each of the two following days, for a total of 25 miners operational on 11/26/2019. 25 miners draw about 60KW, about 1.2% of the power draw promised on Oct 31. The fleet stood at 25 miners for over 6 months, through 6/7/2020, when installation of the remaining 19975 miners began. On 8/12/2020, all 20,000 miners were finally installed (nine months after the contracted RFU date). These delays in installation of a large inventory of ready-to-install miners had significant economic consequences for SBI.

Shortly after the miners were completely installed, abnormally high failure rates were observed. This drastically reduced the datacenter's hashrate, and the miner revenue actually achieved. Figure 15 - Measured Daily Average Hashrate plots the actual measured hashrates achieved by the subset of miners that were operational in the datacenter.[46] Notice the declining trendlines starting in late 2020 as the miners began to fail, and were not promptly repaired. The hashrate predicted by the SBI model and the specifications of the 20000 Canaan miners installed is 723,314 terahash.[44]

6.6.2 Measured / Observed Datacenter Environment

The most important contributor to datacenter environment problems is the outdoor temperature and its impact on intake temperature for the miners. There are two sources of data for outdoor temperature: Historical weather observations and the data recorded in the Lancium log files. Unfortunately, the Lancium data didn't start recording outdoor temperature until July 2021, a month after our miners were removed from service. It does not appear that Whinstone monitored datacenter temperatures during the time period SBI operated its miners, so actual datacenter temperature data is not available.

Historical temperature tables are available on several web sites. Daily weather data for the interval of November 1, 2019 through June 30 2021 was obtained from the Weather Underground web site.[47] The site of observation is the Easterwood Field Station, at the Easterwood Airport in College Station Texas, about 42 miles east of the datacenter. The actual climate at the datacenter should be within a degree of these reported temperatures on the average. This data was analyzed in detail in an Excel spreadsheet.[48] The daily high, average and low temperatures are plotted in Figure 17 - Temperature Observations.

Temperature Observations

Figure 17 - Temperature Observations

Several important points should be noted from the historical temperature observations in the region. The red line on the graph is the high temperature observed each day. The grey line is the daily average temperature, and the blue line is the daily low observation. The dotted red line is set at 85.1°F, which is equivalent to the 29.5°C maximum temperature required by the hosting agreement.[2] Any excursion above that line requires supplementary cooling (such as operation of the wet curtain wall) to avoid overheating the miners. According to the daily maximum temperature historical data, that temperature was exceeded 205 days during the 607 days of miner deployment (33.8%). The maximum temperature

achieved was 102°F (38.9°C) on August 16 and 28, 2020. Also of note are the days below freezing (shown by the dark blue dotted line at 32°F (0°C)), where the wet curtain wall could suffer damage. This occurred on 16 days (2.6%). The minimum temperature recorded during this interval was 6°F (-14°C) on Feb. 16, 2021, during a cold snap where the average temperature was below freezing 8 consecutive days. Five of these days were below 23°F, which is equivalent to the -5°C minimum air intake temperature permitted by the miners. If the miners are operated continuously with input air this cold, they should self-heat and not experience severe problems. But, if the miners are shut down and allowed to freeze (for example because of a prolonged grid power outage or deliberate shut-down in order to sell their power to the real-time power marketplace), the thermal shock when they restart could be damaging, and there could be condensation problems. Obviously, the design and implementation of the Rockdale datacenter was inadequate to meet the specifications of the Canaan miners, given these climate conditions.

6.6.3 Measured Miner Failure Rates

Miner failure rate data is available from several sources. Unfortunately, a full telemetry records for miners do not exist or are not available for the entire installation interval. The sum of Figure 19 - Unresponsive Miners and Figure 20 - Not Hashing Miners has a slope of approximately 5% negative, which means miners were failing much faster than expected and they were not being repaired at an adequate rate. More detailed analysis of this data appears in section 6.7.1.

6.6.4 Measured Miner Cluster Performance

Over the 20 months of deployment in the Whinstone Rockdale datacenter SBI's 20,000 miners (or more correctly, the portion of them that were installed, activated and had not yet failed) managed to mine 769 Bitcoins, 258 BCH and 205 BSV,[44] for a total actual mining revenue of $23,013,508. The BCH and BSV mined contributed about 0.6% of this revenue, so the analysis in the rest of the paper will focus on bitcoin only. It is interesting to note that because of the difficulty of mining bitcoin, when you average it across the pool, only about 4% of the miners installed actually managed to find a valid bitcoin during the installation interval, but the miner pool soothes it out to an average fleet productivity. This fleet productivity is approximately 50% of the expectations (which were based upon assumptions that Whinstone would provide an environment conducive to miner reliability, as implied in the hosting agreement).

6.7 Investigation of Rockdale Data Center

Several approaches were employed to investigate the performance of the Whinstone Rockdale datacenter. Available log files were analyzed in order to quantify the actual performance of the miner fleet. Monthly power invoices were analyzed to determine the actual consumption of the datacenter, and determine if that correlated with the performance of the miners. Various communications between Whinstone, SBI, and various members of the supply chain were evaluated. Failure analysis was performed on malfunctioning equipment. Site inspections (with photos, videos, and expert's observations) were performed and analyzed. Several miners were removed for teardown and laboratory analysis.

6.7.1 Log File Analysis

Log files are recorded by datacenters to track vital performance criteria. The most detailed log files we were able to discover come from Lancium, and were collected in conjunction with their power control of the datacenter. If Whinstone kept additional log files as it should have, those log files have not been produced/disclosed.

The data from the miner pool is summarized in Figure 15 - Measured Daily Average Hashrate and Figure 16 - Actual vs. Anticipated Mining Revenue shown above. Certain aspects of this data are incomplete, but it does adequately represent the overall efficiency of the datacenter for the entire deployment interval.

The Lancium data is contained in a large Coma Separated Value (.CSV) text file[49]. This file consists of 61,289,479 individual one-line records, with 19 fields per record. Total file size is 6,008,688,522 bytes. There are 26 different types of records, identified by an integer in the ID field of the CSV according to this table[50].

id	title	display_unit	description
1	Frequency	hertz	Frequency
3	Unresponsive	miner	Number of Registered and enabled Miners that have not responded to a Measurement command.
6	Operational	miner	Number of Registered and enabled Miners that have responded to a Measurement command & evaluated as Operational. (Criteria may vary based on model or firmware)
7	Not Hashing	miner	Number of Registered and enabled Miners that have responded to a Measurement command but have a hashrate of zero.
9	Hashrate	petahash / second	Hashrate of the Miners in Petahashes per second (PH/s).
10	Active Power	megawatt	Active Power
11	SPP	USD	Settlement Point Pricing
12	Demand Award	megawatt	Demand Response Award
13	Clearing Price	USD	Demand Response Clearing Price
14	Current L1	A	Active Current L1
15	Current L2	A	Active Current L2
16	Current L3	A	Active Current L3
23	Target Test	watt	
24	Target	megawatt	Target
25	MPC	megawatt	Max Power Consumption
26	LPC	megawatt	Low Power Consumption
27	Controlled	miner	Number of registered & enabled Miners correctly responding to a Measurement command and was evaluated as Controlled. (Criteria may vary based on model or firmware).

28	Heat Index	°F	Heat Index
29	Humidity	%	Humidity
30	Temperature	°F	Weather Temperature
31	Active Control	miner	Number of Miners which the Control Loop is sending commands to. Positive numbers = Enable commands | Negative numbers = Disable commands. Resets to Zero when no commands sent. Not cumulative.
32	PFR+Target	megawatt	The target value for the Control Loop. This is the value that the Control Loop is trying to achieve.
33	Online	miner	Number of Registered and enabled Miners that have responded to a Measurement command.
34	Total	miner	Number of Registered and enabled Miners that have responded at least once.
35	Control Enabled	miner	Number of registered and enabled Miners that are registered as Controllable.
66	LMP	USD	Location Marginal Pricing

Table 1 - Lancium Indicator Types

Each of the 61 million+ records, identified by ID type as containing a specific telemetry reading. Records all have timestamps identifying the date and time of the entry with millisecond precision. The date range covered by the dataset spans from 2021-03-23 through 2021-12-31, although not all data types were recorded over this entire range. The most interesting ID types for the SBI miners are Unresponsive, Operational, Not Hashing, Hashrate, and active power, which span the active interval from early April 2021 through June 2021 (about the last four months of the approximately 20-month deployment). Before that, the Lancium telemetry was apparently not being collected for the SBI miners. However, these four months of data are instructive about the deterioration experienced by the fleet of SBI miners.

The data from this CSV was imported into and analyzed by a spreadsheet program. Only about 1.6% of the total CSV log can be imported into Microsoft Excel due to Excel's million-line limit, so a larger capacity cloud spreadsheet called RowZero[51] was used to process the entire data set. This processing involved first filtering the data to only include the lines associated with the indicator value of interest (for example indicator value 7 for the miners that were not hashing). Then, additional filtering was applied to select specific populations of the data in that indicator (for example, filtering on Client ID=2 to select the SBI miners as opposed to ClientID=6 which also appears frequently in the dataset but indicates miners from another customer – believed to be Rhodium). The resulting filtered data was sorted chronologically based upon the timestamp column (some of the records were recorded in the CSV out of sequence), and finally, graphs of the resulting trends were produced. Here are examples:

Lancium Data: **Operational** filtered on: Client ID=2; Indicator=6; Miner_Model=A10; sort old-new

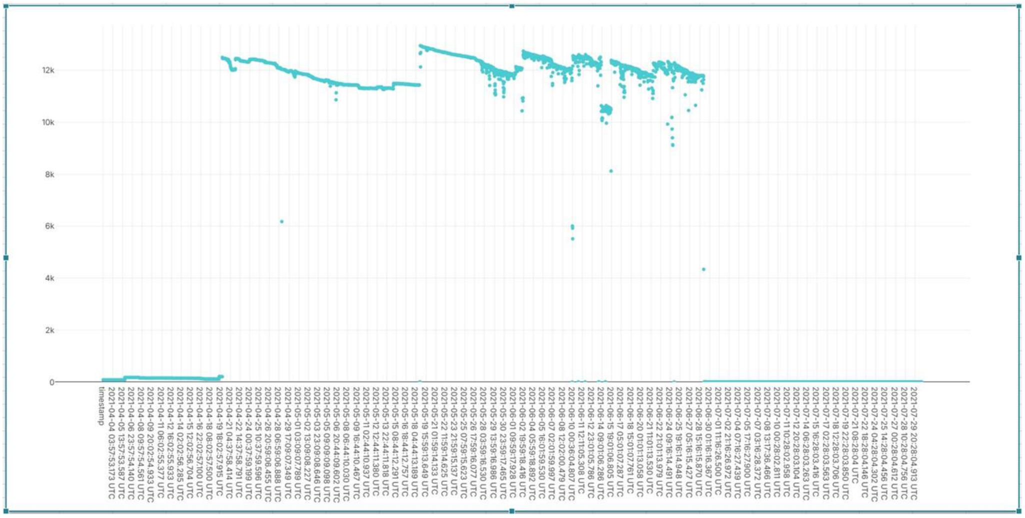

Figure 18 - Operational Miners

Figure 18 - Operational Miners shows the total count of miners configured in the network. Notice that only about 13,000 of the total installation of 20,000 miners appear on this graph, indicating that there

are configuration, networking, control and/or reliability problems with the remaining approximately 7000 miners.

Lancium Data: **Unresponsive** filtered on: Client ID=2; Indicator=3; Miner_Model=A10; sort old-new

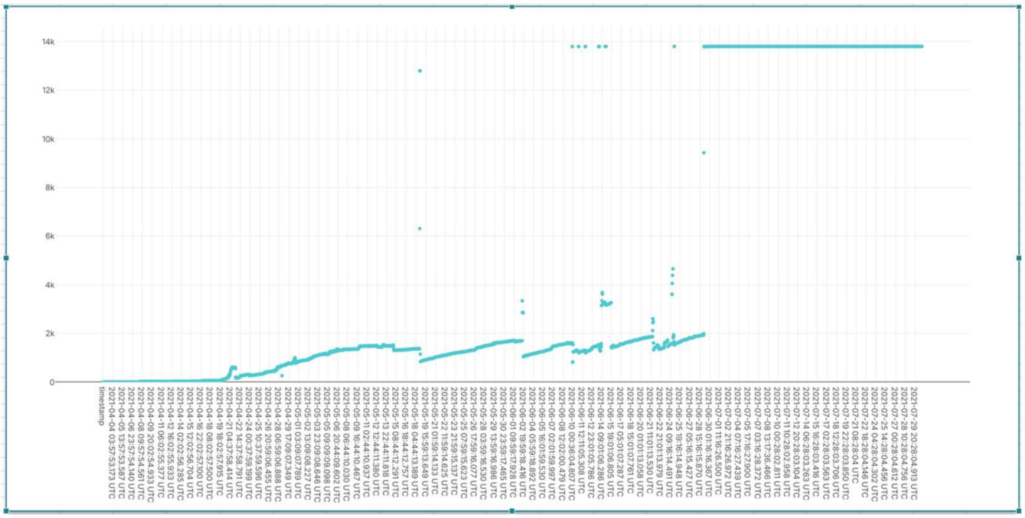

Figure 19 - Unresponsive Miners

Figure 19 - Unresponsive Miners describes the miners in the fleet that are configured, but are not responding to queries from the Lancium control software. Note the trend starts near zero in April 2021 (when Lancium brought the SBI fleet under its control, and most of the miners had not experienced the excessive heat of a Texas summer without the benefit of operating wet curtain wall cooling) and steadily increased to almost 2000 unresponsive miners. There were a few events where the number of unresponsive miners abruptly decreased somewhat, probably due to mass reboots or repair operations, but the overall trend is still an unacceptably large number of unresponsive miners – approaching 10% of the fleet.

Lancium Data: **Not Hashing** filtered on: Client ID=2; Indicator=7; Miner_Model=A10; sort old-new

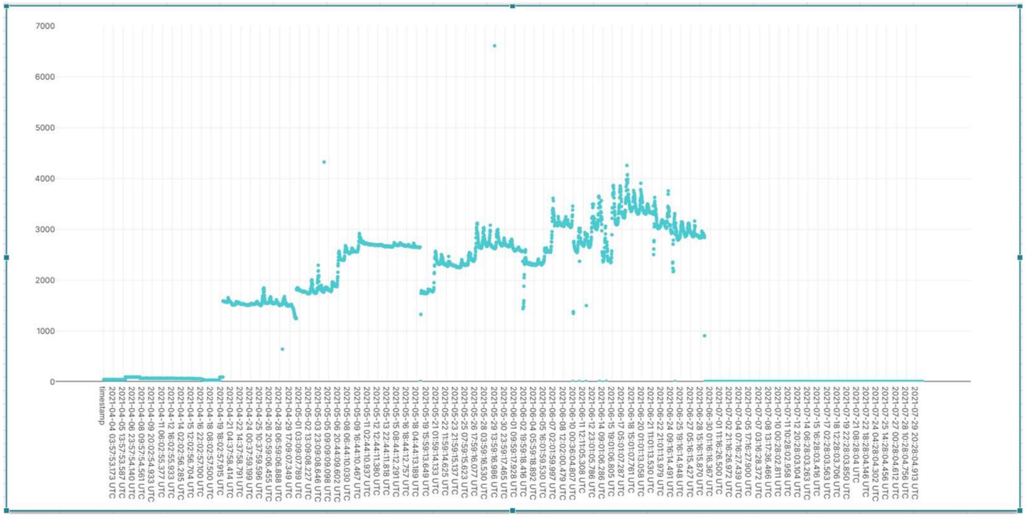

Figure 20 - Not Hashing Miners

Figure 20 - Not Hashing Miners shows yet another failure mode of the miners. These miners are able to respond to Lancium control system queries, but are not performing valid hashing operations. This is probably due to partial hardware failures or overtemperature shutdowns of miners. Note the trend starts near zero in April 2021, and increases to over 4000 miners (20% of the fleet). Once again, reboots or repair operations can temporarily return some of them to operational status, but the fleet quickly deteriorates back to an unacceptably large failure rate trendline. This not hashing state is particularly troubling, because these miners in the not hashing state are likely drawing at least some of their rated power, contributing to overheating nearby miners and incurring hosting charges (which are calculated based upon total power draw), but returning no value to SBI in the form of mined bitcoins. In a well-run datacenter, with good environmental controls and adequate repair responsiveness to failed miners, the graphs of the non-responsive and not hashing reports should be near zero, and nearly horizontal.

Lancium Data: **Hashrate** filtered on: Client ID=2; Indicator=9; Miner_Model=A10; sort old-new

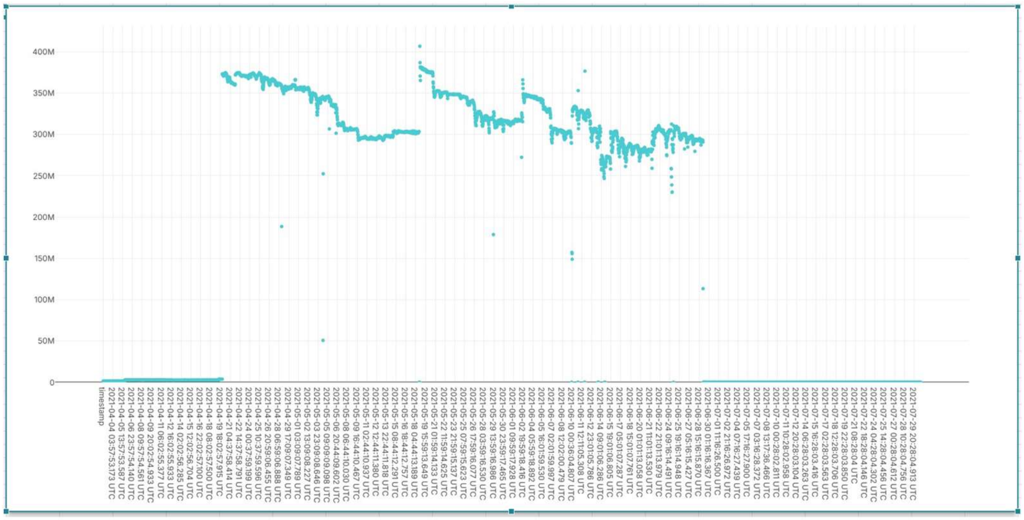

Figure 21 - Total hashrate

Figure 21 - Total hashrate shows the overall work done by the fleet. Notice the general downward trend over the four months monitored here, indicating miners were losing capacity or rapidly dropping out of the pool, and no corrective actions were being taken. The best practice shape of this curve should be nearly horizontal, and near the theoretical hashing capacity of the full fleet of miners, since when a miner is not hashing, the Whinstone “Active Remote Hands” service should immediately detect that and correct the problem.

It is probably not a coincidence that the times of large slope increase in the graphs for unresponsive or not hashing miners, or the times of steep decrease in hashrates (indicating an unexpectedly large frequency of miner failures) correlate with times where the outdoor temperature is above the 29.5°C (85.1°F) limit for intake air temperature as indicated on Figure 17 - Temperature Observations. This correlation indicates that the cooling in this datacenter is strongly implicated as inadequate to achieve reliable operation of the miners.

6.7.2 Root Cause Theories

It is obvious from the above evidence that the SBI miner fleet was not performing as expected and required by the hosting agreement in the Whinstone datacenter. After careful analysis, several contributing factors and the failure modes they caused were identified, and Whinstone’s contribution to the root causes of, and failure to resolve the problems were recognized. Table 2 - Root Cause Theories summarizes these observations (details are provided in the sections below).

Issues	Failure Modes Caused	Whinstone Culpability
Datacenter site and building design problems	Overheating and contamination of miners	Exhaust louvers are a choke point in air flow through the building. Poor dust control
Miner installation problems	Miners overheating caused shutdowns and premature failures	Seals between the miner exhaust ports and hot aisle were leaking, allowing hot air recirculation
Miner firmware and configuration problems	Incorrect configuration and firmware loads caused poor performance	Failed to verify all miners were running up-to-date firmware and correct configuration parameters
Incorrect air filters on building intakes	Dust / particle / insect contamination caused premature failures	The “bug screens” on air intakes were inadequate to exclude windblown dust
No air filters on cooling air intakes	Dust / particle / insect contamination caused premature failures	No air filters on building intake air supply, allowing dust from cold aisle to contaminate miner circuitry
Wet curtain wall was never enabled	Overheating caused by air exceeding 29.5°C contract / 30°C miner maximum spec	Failed to operate wet curtain wall during times when outside temperature exceeded 29.5°C (84°F)
Inadequate cleaning / dust accumulation	Dust infiltration into miners, coating heatsinks, contaminating fan bearings	Allowed dust to pass through curtain wall, and then failed to clean it from floors, racks, shelves, miners
Failure to monitor miner status	At times up to 1/3 of the miner fleet was not mining	Did not routinely monitor the status of the miners or report those that had failed as required in Active Remote Hands agreement
Miners were not repaired promptly	Backlog of failed miners adversely effected fleet performance	Failed to repair the broken miners over multi-month intervals, contrary to Active Remote Hands agreement
Power interruptions	Mining performance declined during heavy electrical loads	Suspect demand response / real-time markets were diverting power from the miner fleet at times without SBI approval
Inadequate notice of planned interruptions	Frequent power and networking interruptions reduce performance	Whinstone failed to provide the advanced notice required in hosting agreement for many outages
Other thermal loads in Building B	Input air to SBI miners was heated by miners from other owners (Riot, Rhodium, etc.)	Failed to isolate the hot / cold aisles between SBIs portion of the datacenter and sections serving others
Backflow through failed miners	If a miner fails, hot aisle air can backflow through it, overheating nearby miners	Failed to promptly repair failed miners, or remove / seal hot aisle exhaust ports to prevent backflow, impacting reliability
Imprecise reporting of power use	It often took months to receive actual power use, slowing down responses	Whinstone collected monthly hosting fee based upon expected power usage, corrected months later

Table 2 - Root Cause Theories

6.7.3 SBI Responses to Problems

SBI made many efforts to work closely with Whinstone to improve the performance of the miner fleet. In general, those communications from Whinstone were infrequent and not as candid as they should be based upon generally accepted data processing practices between clients and datacenter hosting companies.

6.7.4 Crypto Mining Return on Investment

The return on investment of the Rockdale datacenter was far below SBI's expectations. This was due to a combination of many of the factors shown in Table 2 - Root Cause Theories.

6.7.5 Comparison with Russia Data Center

Figure 22 - Monthly mining revenue - Texas vs. Russia plots the monthly mining revenue from the 20,000 miners installed in the Whinstone Rockdale datacenter,[44] and also the monthly mining revenue from an identical set of 20,000 miners installed in the Bitriver facility in Bratsk Irkutsk Oblast in East Russia.[52] The Russia installation lagged the Texas one by about six months, and the Russia datacenter has a different outdoor environment but otherwise the equipment was comparable.

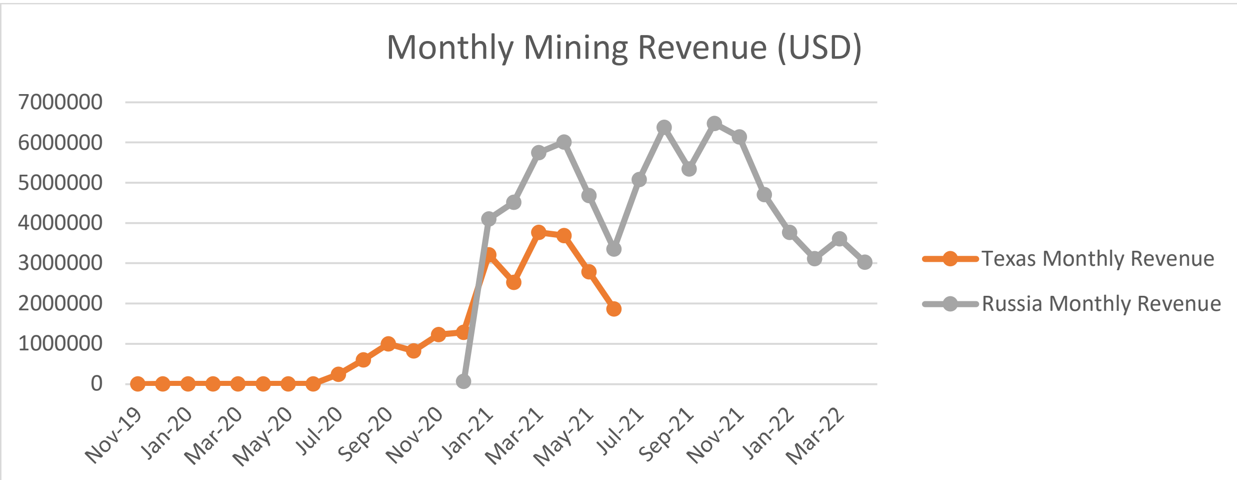

Figure 22 - Monthly mining revenue - Texas vs. Russia

Notice the average operational revenue was about 2X higher for Russia during the core operational months, and the area under the curves (representing total site revenues over the full operational intervals) was over 3X higher.

6.8 Site Visit Evidence

At the request of SBI and Carson Smith, on 6/24/2021, Nicholas Foster of Kaboomracks visited the Whinstone Rockdale facility to assess the condition of the datacenter buildings, power / cooling infrastructure, and the SBI miners installed there. This visit was about a week before the hosting contract was terminated and the removal of the miners began. Kaboomracks specializes in buying, selling, hosting, and advising for crypto mining equipment.[53] Mr. Foster is an acknowledged expert on the infrastructure and configurations for large-scale cryptomining datacenters. He spent significant time[54] touring the facility, taking photos, recording videos and noting detailed observations. This section highlights some of the most important discoveries he made. Phil Isaac made a site visit on 11/07/2024 to observe more recent conditions.[55]

6.8.1 Exterior of Data Center Building

The overall plan of the site can be seen in the overhead view on Figure 6 -Whinstone Rockdale, TX Datacenter Aerial View. Most of the evidence in this section related to the Southern two thirds of Building B (as indicated) where the SBI miners were hosted.

6.8.1.1 Analysis of Exhibits: Photos, Videos and Interviews

File Name	Content
KABOOM_0000135.pdf	Main entry gate, signage, fence, workshop
KABOOM_0000196.pdf	Outdoor view looking south between buildings A and B
KABOOM_0000202.pdf	Close-up view of dusty ground surface and roadway

6.8.1.2 Site Conditions

The overall conditions of the 100-acre (40.5 Hectare) site in Milam County, Texas, described in this reference:[56] are the primary contributors to the mechanical breakdowns and under performance of the SBI miners. Inadequate measures were taken to control blown dust on the site. No pavement or groundcover was used on the grounds surrounding the datacenter buildings, the hardpan earth was pulverized under vehicle traffic and the resulting dust was drawn into building intake louvers, contaminating the datacenter interior.

6.8.1.3 Environmental Conditions

The specific character of the dust on this site may have been especially problematic. Alcoa operated the largest aluminum smelter in the US for 56 years less than a mile from the datacenter site. It processed over a million pounds of alumina ore powder per day into aluminum metal. Alumina is a fine, highly abrasive white powder that is often used in sandpaper and grinding wheels. It is also used in thermal insulators.[57] It is likely that some of this material was windblown over the years from the Alcoa refinery into the soils surrounding the datacenter, making the dust on the site highly abrasive and insulating (very bad for electronics, especially because of possible reduction in the effectiveness of heatsinks and the life of cooling fan bearings). Fly ash from the coal-fired power plant that operated adjacent to the Alcoa refinery for decades could have also contributed contaminants in the soils and dust onsite.

On December 16th, 2024, I went to the Word Tiana (WT) Supply Chain warehouse in Houston, Texas to inspect the miners that were removed from the Rockdale datacenter. They are stored there in approximately 85 large wooden crates. Two of these sealed crates were opened, and a much dust from the Rockdale was still apparent in and around the miners. I collected several dust samples using contamination free techniques, and sent them via controlled chain of evidence for chemical analysis. I selected five of miners at random, and placed them in sealed packages, and sent to my lab in Wheaton, Illinois.

Figure 23 - Crated Miners in Houston Warehouse

Figure 23 - Crated Miners in Houston Warehouse is a view of approximately 200 miners in their shipping crate. They had been in storage undisturbed in this state for approximately 40 months. Notice the fine brown dust apparent on all surfaces of the miners. I swept several grams of this dust into a sterile sample vial and labeled it “Sample 1”.

The teardown analysis of the miners revealed many problems that in contributed to the high failure rates experienced in the miner fleet. One of the five miners selected in Houston (model: AvalonMiner 1041, Serial number: AMA1100e1Xuycf2 – C0A10ES2801) was completely disassembled to reveal contamination internal to the device. Figure 24 - Miner Teardown shows the state of the internal components discovered during this disassembly. One of the two ASIC hashing boards containing 120 type A3205 ASIC chips appears at the top of the photo. Notice the thick dust near and around the critical connections to these chips. Below that are three of the heatsinks needed to cool the chassis and ASIC board, also covered with dust (which will reduce their heat transfer efficiency). Below that, one can see the internal components of the PSU, also with thick coats of dust clinging to the components and critical heatsinks. On the right side of the photo are the two primary miner chassis cooling fans, with significant dust accumulation and corrosion evident. Below that is the miner control board (also very dusty), and some of the chassis components. Several grams of the internal dust from this miner

along with additional dust shaken out of the other four miners retrieved from Houston were swept up, put into a sterile vial and labeled “Sample 2”.

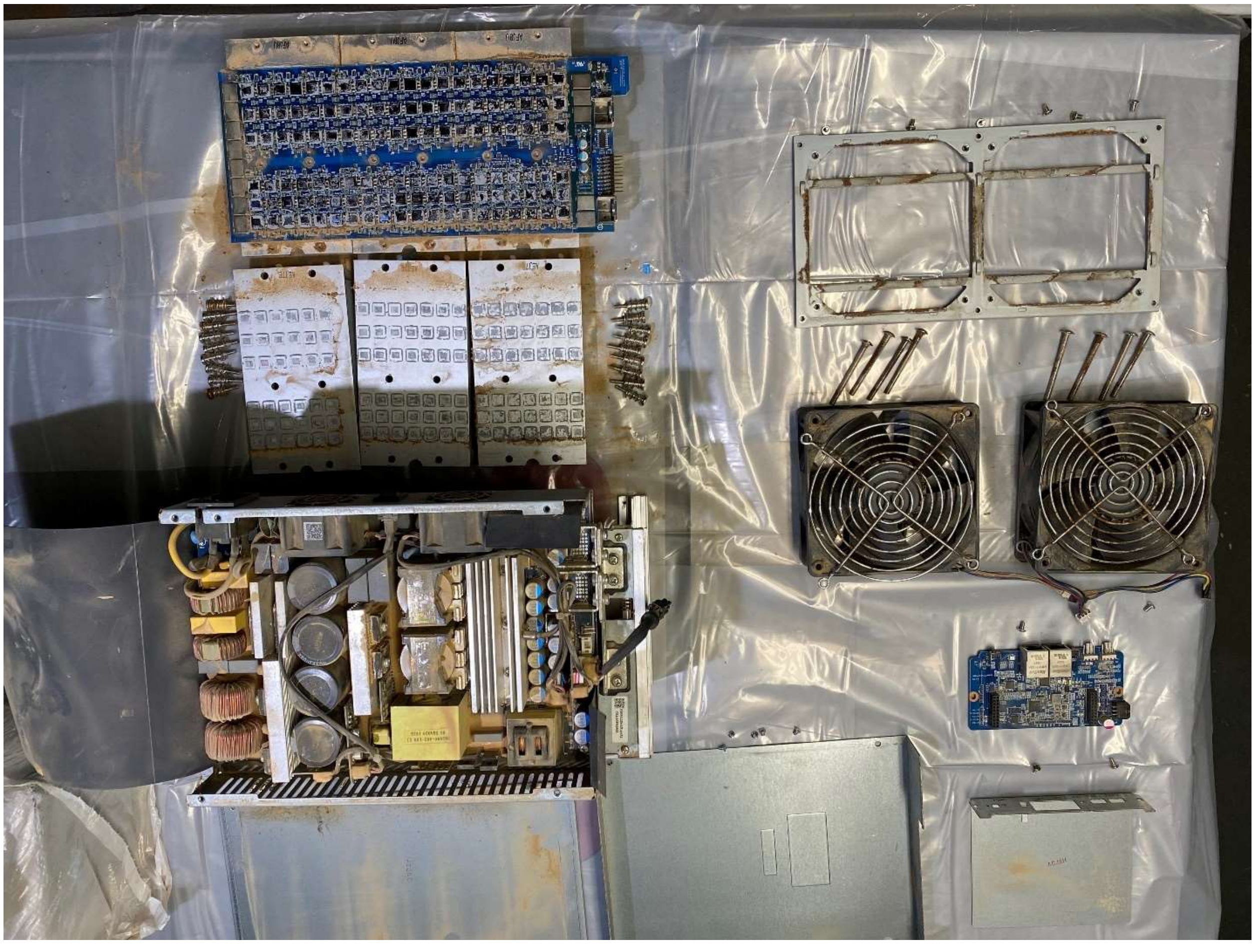

Figure 24 - Miner Teardown

6.8.2 Laboratory Dust Sample Analysis

The two dust samples (sterile vials labeled “Sample 1” and “Sample 2”) were chemically analyzed by MVA Scientific Consultants in Duluth, GA (mvascientificconsultants.com) using techniques including a combination of polarized light microscopy (PLM), scanning electron microscopy-energy dispersive x-ray spectrometry (SEM-EDS), and Fourier transform infrared microspectroscopy (FTIR), as needed. The complete report from MVA Scientific is available here: [58]

The findings show both samples have similar elemental composition, with sample 2 from inside the miners (obtained during teardown) having a wider variety of contaminants.

The report includes 67 optical / electron microscope images showing fine detail on the specific composition of the dust and some of the most interesting particles within it. There are also 49 graphs of EDS and FTIR spectra analyzing the elements composing specific particles in the sample. Knowing the

ratio of elements in these spectra allows the precise identification (from a database of known materials) of type of mineral, metal, organic or synthetic compound in each dust particle or contaminant. Some of the highlights of these images include:

- Rust – Figure A19
- Paint – Figure A23
- Insect part – Figure A25 (a bizarre looking one)
- Elemental analysis - figures A29-A40 showing specific chemistries and identifying the material composing various particles
- Large quantities of magnetic iron particles adhering to a magnetic tweezers - Figure B4 (these could easily short out fine-pitch connections on PCBs)
- Fungal spore – Figure B19
- Foam Fragments – Figure B16 (could be antistatic foam, which is conductive). These are further analyzed in figures B28-B32.

The conclusions from page 4 of the MVA scientific laboratory report are reproduced here for convenience (the full report, including much more detail on the methods, results, and specific findings are available in the above reference).

> **"Conclusions**
>
> Both samples contain a significant volume of particulate and are composed mainly of granular particulate including carbonate minerals, quartz/silicate minerals, and probable cement particles. Plant fragments are present in lesser amounts but are also major constituents (>10% by volume of total particulate). Paper fragments and metal/corrosion particles are present in minor amounts (estimated 1% to 10% by volume of total particulate). Char/soot is a minor constituent of Sample 1. Insect parts, synthetic foam, and other polymer fragments are minor components of Sample 2. Trace (<1% by volume) constituents include pollen, fungal material, synthetic (rayon) fibers, glass fibers, cotton fabric fibers, paint particles, starch granules, rubber particles, and glass fragments. SEM-EDS analysis indicates the presence of chlorine-bearing salts in association with some particles.
>
> **Potential Impact Evaluation**
>
> A survey of internet sources revealed the following potential adverse effects on

electronic equipment that might be associated with the types of particulate detected in the submitted dust samples:

Accumulation of dust particles on equipment can act as an insulator, thereby decreasing the ability to dissipate heat from the system and causing overheating of electrical components. Poor contacts in relays, switches and connectors may also result. Additionally, dust accumulation can interfere with moving parts such as fans, thus exacerbating problems with overheated equipment.

Conductive materials such as the metal particles detected in the submitted samples can settle on exposed circuitry and lead to short circuits.

Plant matter and clay minerals (aluminosilicate) are present in the dust. These materials tend to hold moisture and can add to humidity, increasing the possibility of electrical arcing. While, in this case, the dust samples appear to be relatively dry, it should be noted that increased moisture as well as the presence of salts can lead to corrosion issues including degradation of electrical connections. Further, moist dust acts as a partial conductor and can initiate electrical shorts or high voltage discharges.

Release of volatile organic compounds (VOCs) due to off-gassing of polymer materials (synthetic foams, plastics) at room temperature or out-gassing under conditions of increased heat or in the presence of a vacuum has the potential to corrode or otherwise adversely impact the performance of sensitive electronic components."

6.8.3 Interior Cold Aisle

Two cold aisles flank both long sides of Building B. As shown in the building cross-section in Figure 11 - Whinstone Datacenter Cooling Architecture, the cold aisles receive air from the wet curtain wall, and it appears that the miner chassis and PSU fans were to create a negative pressure in the cold aisle, drawing outdoor air into the building through the evaporative cooling walls. The cold aisle also includes the power distribution breaker panels, networking equipment and maintenance access to the miners.

6.8.3.1 Analysis of Exhibits: Photos, Videos and Interviews

File Name	Content
KABOOM_0000145.pdf	View down cold aisle, server racks left, breaker panels right
KABOOM_0000159.pdf	Interior of wet curtain wall on left, breaker panels right
KABOOM_0000168.pdf	Full height view of equipment racks from cold aisle
KABOOM_0000241.pdf	Close-up of breaker panel, showing underground feeds

KABOOM_0000145.pdf[59] is a view straight down the cold aisle of Building B, a distance of about 1050 feet (320m).

6.8.3.2 Cooling Walls

As shown in KABOOM_0000159.pdf [60], the cooling wet curtain walls occupy approximately half of the height of the external walls for the full length of the building. The brown corrugated cooling pads were supposed to be saturated with fresh water that evaporates at a rate dependent upon airflow, humidity, water flow and other factors to cool the air entering the cold aisles on both sides of the building. The manufacturer recommends capacity of 400 gpm (1514 liters per minute) flow per building for makeup water. Unfortunately, according to Whinstone personnel, these cooling walls were not operated during the interval when SBI miners occupied Building B, and this led to hundreds of days of overheating.[61] See the deposition from Lyle Theriot[62] on pages 136:12 – 137:5; 188:2-19.

6.8.3.3 Air Intake Paths

Outdoor air enters the building through a series of louvers (visible in KABOOM_0000196.pdf [63]), passes through a bug screen, and into the adiabatic cooling pads. The pads should have fresh water sprayed on their top surfaces, and the water works its way down the brown porous media of the pad, saturating it. Any excess water is collected in a gutter below for reuse. Simultaneously, the cooling air passes horizontally through the pad, gaining humidity and cooling down (a process called adiabatic cooling). Then, the air travels across the cold aisle about 20’ (6 meters) and enters the equipment racks shown in KABOOM_0000168.pdf[64].

6.8.3.4 Power Entry Breaker Panels

Reference KABOOM_0000241.pdf [65] shows one of the breaker panels located in the cold aisle. Power arrives into the building from below via heavy cables in a number of underground ducts that connect to the switchgear and one of the transformers just on the other side of the building wall. Power distribution cables exit the top of the breaker panels and are routed through the overhead cable racks into the equipment racks and the PDUs therein.

6.8.3.5 Environmental Conditions

The wet curtain walls never operated during the installed interval of the SBI miners. This was apparently due to delays in securing sufficient water rights for the site [66]. Also, there was a freeze event that caused some of the wet curtain wall equipment to be damaged, and it was not repaired during the time SBI miners were installed. Even if the wet curtain walls were repaired and supplied with adequate water, the thick dust blowing in from outdoors (the bug screen would not stop it) could collect on the damp surfaces of the curtain wall media, turning into mud, and eventually reducing cooling effectiveness and choking off the cooling air flow.

As a result of these problems, during the frequent hot intervals, the air in the cold aisle was well over 29.5°C (85.1°F), violating the terms of the hosting agreement, and causing the miner chassis and their PSUs to overheat. This led to premature miner failures, and a serious decline in mining revenue.

There is limited actual measurement telemetry on the air temperature at the miner air intakes. This is due to difficulties in locating and receiving production of any records that Whinstone may have kept regarding cold aisle temperatures. However, it is easy to infer that the temperature at the miner air intakes could not be cooler than the reported outside temperature, because in the absence of an

operating wet curtain wall, there were no means to lower the temperature of the cooling air. In actuality, the temperature of the intake air at many miners was significantly warmer than ambient due to recirculation of hot aisle air because of poor sealing of the sequestration wall, or recirculation of air backwards through the subset of miners (up to 30%) with failed cooling fans, control boards or PSUs.

6.8.4 Miner Racks

The miner racks are the primary physical support and cooling air direction mechanism for the miners. They reside on the inner portion of the cold aisles, opposite the wet curtain walls. Based on their estimated width, Building B has about 322 racks in each cold aisle, for a total of about 644 in the building. Their mechanical structure of each rack must be adequate to support the weight of 48 miners (at 11.4KG / 25 lbs. each), four PDUs, a switch and almost 100 cables, for a total of around 1400 lbs / 620Kg per rack. Of the approximately 644 racks in Building B, the SBI miners occupy approximately 417 of them (20,000 miners divided by 48 miners per rack).

6.8.4.1 Analysis of Exhibits: Photos, Videos and Interviews

File Name	Content
KABOOM_0153.pdf	Front view of five racks showing density of arrays, and also how power and LAN wiring drops to miners and status LEDs
KABOOM_0165.pdf	Oblique view showing a wall of seven racks
KABOOM_0157.pdf	Close-up of miner / network shelves with thick layer of dust
KABOOM_0000.pdf	

6.8.4.2 Density

This datacenter represents a very high mechanical and thermal density deployment. The thermal density for all of Building B is 75MW / (1050' * 60') Sq. Ft. = 893W/Sq. Ft. or 12.8KW per square meter, which is very high for air cooled datacenters[67] (which are typically well under 150W/Sq. Ft.). This density is significantly over industry norms, and the inability of the infrastructure of the building to keep adequately cool contributed significantly to the problems with this deployment. Because of thermal limits due to design and operational problems with the airflow and cooling systems, data processing best practices would have been to derate the total capacity of Building B from its maximum electrical input capacity of 75MW down to a more achievable 25-50MW. This derating would have completely filled Building B with SBI miners (and perhaps required overflow of thousands of miners to other buildings). Whinstone chose to overload the building.

6.8.4.3 Wiring

Wiring of power and LAN cables is clearly visible in KABOOM_0153.pdf.[68] This wiring brings the power to the PDUs and interconnects the LAN ports with the external networks, providing the electrical support servers need. Although in a few cases these cables could cause some airflow obstruction, it is probably not significant, and the electrical interconnect is probably adequate and didn't appreciably contribute to the poor performance of the datacenter.

There is evidence that certain problems exist in the power distribution wiring. In an August 2020 email thread from Lyle Theriot, it was noted that some PDUs may be overloaded, and H&K electric is going through Building B and marking with tape segments of the power distribution that are not working. [69]

6.8.4.4 Airflow

Cooling air is drawn in from the cold aisle, passes between the equipment rack shelves, and enters the server intake fans. The open space for this airflow is evident in reference KABOOM_0165.pdf.[70] The largest concern arising from the equipment racks is on their rear side, where the exhaust from the miners enters the hot aisle. Any leakage between hot and cold aisles because of poorly sealed miner exhaust ports to the foam sequestration wall will drastically reduce the cooling capacity (more about this in a future section).

6.8.4.5 Dust

These shelves are horizontal surfaces that accumulate the dust that is one of the most serious problems in this datacenter. Reference KABOOM_0157.pdf[71] is a close-up of two shelves in an equipment rack. On the upper shelf, approximately 1/8" (3mm) of dust has accumulated on the shelf, immediately adjacent to the air intake fan of a miner. A finger wiped the lower shelf to give an idea about just how thick and fine this dust is. This level of contamination is contrary to good data processing best practices. It is obvious that inadequate steps are being taken to prevent dust from entering the datacenter, inadequate cleaning is being performed, dust contamination is entering the servers, and this contamination is a strong contributor to early miner failure. A chemical analysis of dust samples taken from decommissioned miners reveals the potential harm this dust could cause to electronics like the Canaan miners. See dust analysis report [58] and section 6.8.2.

6.8.5 Individual Miner Devices (as Installed)

The exhibits have many views of individual miner devices as installed in their equipment racks. Understanding the conditions individual miners are experiencing is key to understanding the root causes of this datacenter's underperformance.

In reference KABOOM_0203.pdf,[72] four miners are visible, sitting on two shelves (no mechanical fasteners were apparently employed to hold them in place – just gravity). The thick brown wires on the right are the power whip cables connecting the miners' PSUs to the PDUs. The thinner cables on the left are the LAN cables to the Ethernet switch just below. Cooling air is drawn from the cold aisle, through the four (or sometimes five) fans in each miner, and exhausted to the hot aisle which is immediately behind the sequestration airflow baffle insulated board visible behind the miners. One can also see some of the mechanical support hardware for the rack.

6.8.5.1 Analysis of Exhibits: Photos, Videos and Interviews

File Name	Content
KABOOM_0153.pdf	Wall of servers showing many status LEDs
CANAAN-00001.pdf	Manual for miner showing meaning of status LED
KABOOM_0203.pdf	Four miners installed on two shelves
KABOOM_0181.pdf	View of two dirty miners, showing an insect, corrosion, dust
KABOOM_0000302.MOV	Video showing inspection of two 1041 miners on a shelf

6.8.5.2 Status LEDs

Miners have status LEDS whose meaning is described in Page 4 of this reference: CANAAN-00001.pdf.[73]

The status LED is multicolor, with these meanings:

- White: Initializing / Software operations
- Green: Normal mining conditions
- Yellow: Initializing
- Red: Overheat alarm
- Off: Power disconnected, switched off or PSU failure

Reference KABOOM_0153.pdf[74] is a representative view of the lower portion of about five racks of servers, with approximately 100 status LEDs visible. The expectation is that in a correctly functioning and maintained datacenter, 99% of these units should be in the normal mining condition (green status LEDs), and statistically (based upon expected 1% failure rates) about zero or one could be red / yellow / off in this subset of miners. The visible LEDs in this photo show this status:

• Green: Normal mining conditions	40 miners
• Yellow: Initializing / abnormal software state	46 miners
• Red: Overheat alarm	13 miners
• Off: Power disconnected,	1 miner

Only about 40% of the miners whose status LEDs are visible in this photo are reporting a normal mining condition, while the remaining 60% seem to be in other states that are not contribution to the mining hashrate (and could be drawing useless power). Of course, all racks may not be as bad as this one, but it does seem to be representative of a set of widespread problems.

6.8.5.3 Physical Conditions

The mining racks appear to provide adequate mechanical support for the weight of the miners installed upon them. The cable management (cable ties to rack structure) appears to keep cables sufficiently away from the airflow paths and protect them from mechanical damage. There are portions of the racks that may harbor dust that could contribute to miner failure rates if not promptly and thoroughly cleaned (which could be difficult, due to the mechanical complexity of the design, and need to access shelves at least 20‘ / 6M off the floor).

6.8.5.4 Airflow Management

The cold aisle side of the racks do little more for airflow management than provide open paths for the cooling air after passing through the intake louvers, bug screens and wet curtain walls to enter the miner fans. The hot aisle side of the racks have significantly more important functions (to be described later).

6.8.5.5 Dust / Contamination / Corrosion

Reference KABOOM_0181.pdf[75] is a very telling image to demonstrate the problematic conditions for the miners. The first thing to note is what appears to be a desiccated insect (something resembling a moth) stuck to the finger guard on the leftmost miner chassis cooling fan. The wingspan of this insect appears to be at least 0.5”, so it is obvious that contamination of that size or smaller can enter the datacenter freely. Also notice the degree of corrosion on the steel fan guards, indicative of poor humidity control in the cold aisle. This makes sense, as relative humidities over 80% are common in this region of Texas. If the finger guards have corroded to this degree after only about a year of deployment, it is reasonable to assume that more vital components inside the miner chassis and their PSUs could have experienced similar levels of destructive corrosion (which was verified during the miner teardown).

Finally, notice the brown dust clinging to the surfaces of the fans, connectors, cables, and rear of the PSU enclosure on the top of this picture. It is obvious that if this much dust is visible here, at least that much must have been sucked by the strong fan airflow into the air intake of the miner. This dust can cause many problems, including depositing on heatsinks, insulating them from airflow, getting into fan bearings, grinding them up and causing premature failures, and depositing on sensitive internal circuitry, changing its conductive properties and (in the worst case if the dust is conductive or hydroscopic) causing internal short circuits or arcing. See the MVA laboratory analysis report[58] for details on the dust composition and its potential impacts on electronics. Best practices for data processing equipment would be to provide high arrestance air filters on the outdoor air inlets to the building, right at the air intakes to the miner fans (especially in dusty environments), or both, but neither of these were installed.

6.8.5.6 Reverse Airflow

By design in this datacenter, the hot aisle is at a higher pressure than the cold aisle. Unfortunately, if a miner fan fails, its fans will backspin allowing hot air from the hot aisle to come through the miner backwards. In video reference (at timecode 00:08) KABOOM_0000302.MOV[76], there is an observation of this happening: "there is a dead one on the shelf, there is hot air running through it in the wrong direction". This can be disastrous, as the hot air passing backwards through a miner with a failed fan, PSU or control board enters the cold aisle, and is immediately sucked into nearby operating miners. Because under these conditions their input cooling air is significantly hotter than allowable limits, those miners will overheat, which could cause them to fail prematurely and create a cascade reaction. There is evidence in several of the Kaboomracks videos [77] [78] [79] and photos that the miners tend to fail in clusters, and this backflow is a likely cause. All miners in this condition should have been immediately discovered and repaired / replaced, or at least their errant airflow paths should have been quickly covered over as part of the maintenance procedures.

6.8.6 Interior Hot Aisle

The hot aisle in Building B accepts the exhaust airflow to on the order of 30,000 miners occupying cold aisle racks on both sides (20,000 from SBI, plus an additional approximately 10,000 from other tenants in Building B, probably including Rhodium). It is intended to direct the primarily horizontal airflow exhausting from the rear of the miners on both sides of the hot aisle vertically, and out of the exhaust louvers on the sides of the clearstory roof structure. In the following reference, note the amount of dust accumulated in the hot aisle. The most likely way for it to get there during typical operation would be through the (non-operating) wet curtain wall, across the cold aisles, right through the miners chassis and PSU, and depositing on horizontal surfaces as the airflow takes a 90° bend to head up to the clearstory. A possible alternate mechanism for deposition of this amount of dust in the hot aisle would be for it to blow backwards into the clearstory exhaust louvers during one of the infamous gale-force dust storms that happen occasionally in this part of Texas.

6.8.6.1 Analysis of Exhibits: Photos, Videos and Interviews

File Name	Content
KABOOM_0185.pdf	End view from outside the hot aisle
KABOOM_0229.pdf	Interior or hot aisle, showing about 50 racks on both sides
KABOOM_0227.pdf	Interior of hot aisle with miner exhausts visible
KABOOM_0235.pdf	Hot aisle close-up of miner exhausts showing bad seals

6.8.6.2 Baffles

As shown in reference KABOOM_0185.pdf[80], the hot aisle is constructed from the metal framework of the rear structure of the equipment racks outside a layer of foil-backed insulating board. This is intended to create a sequestration barrier that totally isolated the hot air on the inside of the hot aisle from the cooler air in the two cold aisles surrounding. You can see the end view of the equipment racks on both sides, including the sides of the last rank of miners. Also of note is the view of the clearstory vent structure in the roof that accepts airflow from nearby miners and is the intended path for the hot air to exit the building. Louvers on the sides of the clearstory protect the hot aisle and interior of the datacenter from driving precipitation, but also create resistance to building exhaust airflow. The inadequate height of these banks of exhaust louvers is a serious design flaw of the building. More detailed analysis of the airflow in the hot aisle is available in the Phil Isaac Report.[55]

6.8.6.3 Airflow Seals

Reference KABOOM_0229.pdf[81] is a view of the inside of the hot aisle. The exhaust ports from about 50 racks with 48 miners each are visible on each side of this view, representing approximately 25% of the SBI miner fleet. The temperature in this area can exceed 140°F (60°C) when the datacenter is operating at full power.

Panels of foil-wrapped foam board were custom cut to surround the miner chassis / PSU exhaust ports, and installed on the rear surface of the equipment racks. As miners were installed, they were pushed tightly into the holes in these panels, and where necessary some gaps were sealed with duct tape. A tight fit is essential, to avoid air recirculation through any gaps. Unfortunately, as shown in reference KABOOM_0235.pdf[82], many unsealed air gaps exist (note especially the large gaps surrounding the miners on the sixth and eight row from the top of this photo). Pressurized hot aisle air immediately rushes into these gaps, preheating the cooling air in the cold aisle for nearby miners. Many, many instances of this sort of poor installation quality are evident in the site visit photos and videos.

6.8.6.4 Air Paths

The walls that form both sides of the clearstory roof structure are 6’ (1.8m) high, occupying substantially the full length of Building B, with exhaust louvers having an approximate height of 4’ (1.2m) on those walls, providing a total exhaust plenum area of about 8400 square feet (780 square meters). By contrast, the intake air plenums (wet curtain walls) are 10’ high running substantially the full length of both sides (about 1000 feet (305m) of the 1050 feet (320m) total length) of the building, for a total intake area of about 20,000 square feet (1858 sq. m). The small area of the exhaust louvers that must accept the entire cooling flow from up to 30,000 miners dissipating up to 75 megawatts causes the hot aisle and clearstory to have significant airflow restrictions and negative cooling impacts.

6.8.6.5 Overpressure

On a site visit video,[83] the Kaboomracks representative commented on how much pressure and heat existed in the hot aisle. This is due to several factors. The most important one may be the design of the building, where inadequate plenum space was provided by the clearstory roof vents in the hot aisle. This created a reduced flow condition that prevented the miners cooling fans from moving as much as they were capable of moving, due to the louver resistance, and also greatly aggravated the recirculation through any airflow gaps. The clearstory ventilation louvers on the roof of the building that provide the only hot air exhaust are 4 feet (1.2m) high and 1050 feet (320m) long on each side, for a total of approximately 8,400 square feet (780 square meters).

There is another potential concern with overpressure. There are two types of fans in the Canaan Avalon family of miners: two large 120mm (4.7”) primary cooing fans that cool the miner chassis containing the miner ASIC boards and control boards, and two (or on some models three) 40mm (1.6”) fans that cool the PSUs. Both types of fans must move adequate air to maintain miner performance and reliability. Fans have performance curves that plot the flow vs. inlet-outlet pressure differential at various RPM settings. The performance curves of the smaller PSU fans are far below those of the larger miner chassis fans, so that under some circumstances the more powerful miner chassis fans could move adequate air to keep the mining ASICs cool, but the backpressure they create in the hot aisle is too much for the smaller PSU fans to overcome. Under these conditions, the airflow through the PSU stalls, or perhaps even reverses (effectively causing the inlet air temperature for the PSU to be the 140°F (60°C) or hotter temperature of the hot aisle), and the internal components (especially those under the most thermal stress, probably including voltage regulators and switching transistors) can’t dissipate their internal heat production, and the PSUs overheat to the point of failure. These PSUs don’t appear to have the capability to report these overheat conditions through the miner control board software, so they could have cooked for long intervals without any indications (beyond much higher-than-expected failure rates for the PSUs and the miners they run).

A significantly larger exhaust vent area (one method would be via a taller and/or wider clearstory structure), and/or exhaust booster fans (which were discussed at several phases of the building design and construction, but never implemented), as shown in this email thread from Lyle Theriot[84] would have reduced the overpressure in the hot aisle to more acceptable levels, restoring adequate cooling flow to the miners chassis and their PSUs, and preventing many of the failures experienced by the SBI fleet.

6.8.6.6 Recirculation

Gaps like those evident in reference KABOOM_0235.pdf[85] are very damaging to this sort of cooling arrangement. Because of the high relative pressure in the hot aisle, and the inadequate exhaust louver size, air wants to escape through the path of least resistance, which will be through the gaps in the sequestration wall or backwards through failed miner fans, and not through the clearstory louvers to outdoors as intended by the building design. Assuming the input air in the cold aisle is 80°F or 27°C (it was often much hotter than that), and assuming the hot aisle air is 140°F (60°C), if only 25% of the recirculated air was mixed into the cooling flow, input air for nearby miners would exceed 95°F (35°C), and be over the maximum input spec for the miners. This can lead to compound failures, where hot input air for a neighborhood of failed miners causes their exhaust air to get even hotter, potentially causing failures and miner shutdowns, which then provide additional recirculation paths backwards through failed miners, amplifying the failure cycle. This could be an important reason why there seemed to be hotspots and clusters of failed miners in various places throughout the datacenter.

6.8.7 Miner Teardown

Several of the failed miners from the pool of 20000 were removed from service in order to determine their failure modes and probable root causes of those failures. The following section outlines the observations from that process. Two sets of evidence are presented here: photos taken by Kaboomracks in June of 2021 in an on-site maintenance depot in Rockdale, and photos taken in my lab, where I performed rigorous teardown of five of the decommissioned miners.

6.8.7.1 Analysis of Exhibits: Photos, Videos and Interviews

File Name	Content
KABOOM_0117.pdf	Front of dusty server
KABOOM_0121.pdf	Dust accumulation on heatsinks
KABOOM_0123.pdf	Interior dust accumulation
KABOOM_0125.pdf	Dust on connectors and fine-pitch components
KABOOM_0261.pdf	Interior of server, showing possible condensation on dust
SBIC0005892.jpg	Photo of a shattered Toshiba K39N60W N-Channel MOS transistor and also the socket it fits into in the PSU

6.8.7.2 Miner Component Parts

As mentioned above, miners consist of the mining ASICs mounted on miner ASIC boards, a control board, a PSU, a chassis and cooling fans. This section details observations upon close inspection and disassembly of a miner to all of these components.

6.8.7.3 External Condition

As described in previous sections and shown clearly in reference KABOOM_0117.pdf,[86] the miners were subject to dust, corrosion and contamination conditions well beyond any accepted data processing equipment practices. This contributed directly to their premature failure and the suboptimal performance of the installation. Fine dust has accumulated on external surfaces, in and around the fans, and in the connectors. The dust in the fans could contribute strongly to premature bearing failure.

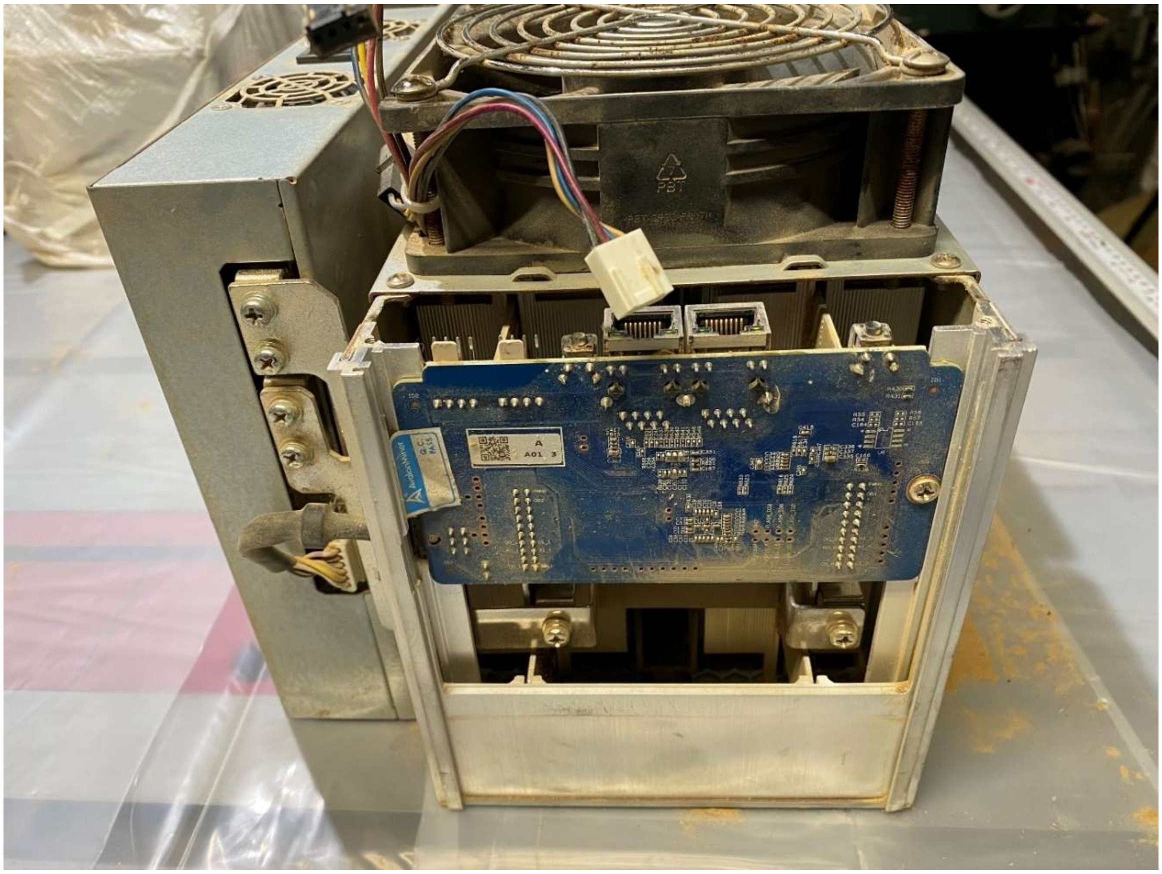

Figure 25 - Miner External

Teardown photo Figure 25 - Miner External is a view of the outside of the miner with one protective cover removed. Notice the dust on the surfaces of the fans and chassis components

6.8.7.4 Internal Condition of Chassis

Reference KABOOM_0123.pdf[87] shows the internal view of the chassis adjacent to the two miner boards (whose heatsinks are visible on the left side). Notice the thick layer of dust on the aluminum panel (the dust thickness is estimated at about two mm (0.1”) based upon the finger swipe that wiped a small portion off). The heatsinks are also extremely dusty, potentially greatly reducing the cooling efficiency of the ASICs and causing overheating and failure.

Figure 26 - Heatsink Bugs

Teardown photo Figure 26 - Heatsink Bugs is a view of the miner ASIC board heatsinks inside of a miner chassis. Notice the dust accumulation that would likely have impeded airflow and heat transfer to the air. Also note several desiccated insects (commonly found in miners during teardown, and indicative of poor contaminant control and poor maintenance).

6.8.7.5 Inner Condition of Power Supply Units

Reference SBIC0005892.jpg[88] includes two photos. The bottom photo shows the inner condition of the PSU from one miner. Note the dust accumulation on the inner surfaces and Printed Circuit Board connections. One key semiconductor device at the center of the lower photo has failed catastrophically. The upper photo is the remains of its external package that was blown off the rest of the device due to significant overheat or overload of the semiconductor chip inside. This type of failure symptom is fairly common in high power systems (and this ~3000 Watt capable PSU certainly qualifies). This is a Toshiba

K39N60W N-Channel MOSFET transistor, rated at 600V drain-source voltage, 38.8A of DC drain current, 0.055Ω on resistance[89]. Its function is to take a higher, unregulated voltage inside the PSU and switch it through transformers to convert it to a lower, more precise voltage that doesn't change with varying AC input voltages or power draw from the miner chassis. Up to four of this basic type of transistor are used in the PSU, associated with the AC input functions of power factor correction, pre-regulation or switching power supply input chopping. Considering its rated power dissipation is 270 Watts, this is likely one of the more highly stressed components in this PSU and as a result would be one of the first components we expect to fail should the operating conditions of the miner fall outside the specified operational limits (such as input voltage, output power or in this case, most likely exceeding its 150°C (300°F) maximum channel / junction temperature rating).

It is likely that this part was overheated due to prolonged exposure to excessively hot input cooling air or poor heatsink performance due to dust accumulation. Another possible explanation is that some nearby circuit was adversely impacted by conductive dust, causing this chip to experience overload, arcing, thermal runaway and catastrophic failure. If the PSU cooling fans experienced starvation due to their flow being overcome by the more powerful main cooling fans causing airflow to stop or reverse, internal components in the PSUs would have exceeded their rated maximum temperatures quickly.

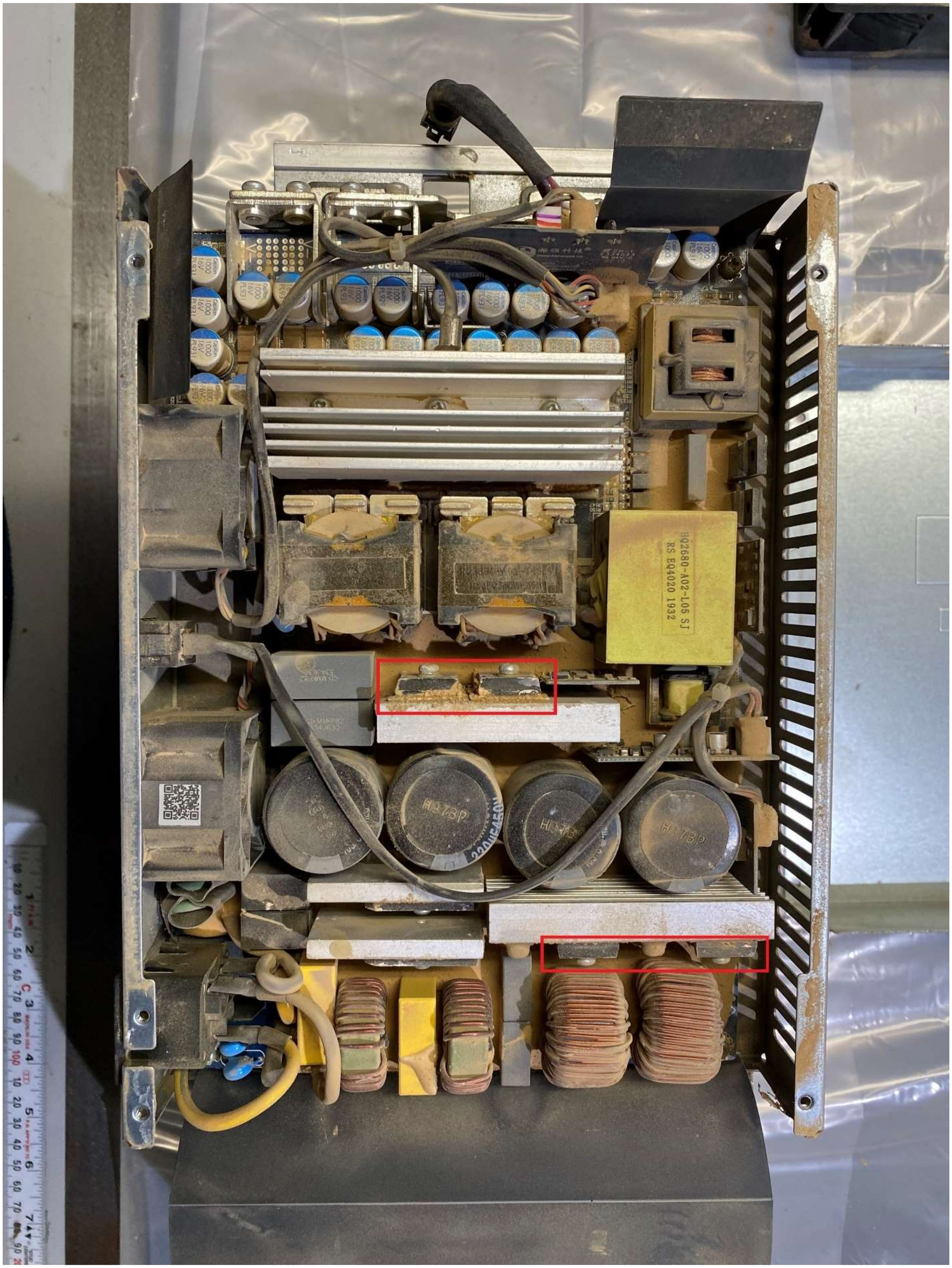

Figure 27 - Power Supply

Teardown photo Figure 27 - Power Supply shows the inner conditions of a miner PSU. 240VAC energy enters through the type C20 power inlet connector at the lower left corner, is filtered by four toroidal inductors, and passes through levels of circuitry to rectify, filter and switch the energy through two large transformers at the center of the assembly. After the energy passes through the transformers, it is rectified, filtered by the 20 capacitors with the blue stripes, monitored and passes out the main busbars visible at the top left to the miner chassis as the 13.5 volt DC (nominal) primary power output. The two cooling fans (one with a QR code) appear on the left of the PSU, drawing in external air and moving it across the aluminum heatsinks to cool the hot internal components before being exhausted out the grating on the right. The four switching transistors (of the type that is reported to be a common failure mode of many of the approximately 7000 miners that failed) are highlighted by red rectangles. If there was inadequate airflow, these heatsinks and attached parts will overheat rapidly. Also notice the thick accumulations of dust on the heatsinks and other components, potentially contributing to the failure modes.

6.8.7.6 Inner condition of Miner ASIC Boards and Heat Sinks

Reference KABOOM_0121.pdf[90] is a view inside one of the miners' chassis immediately after the two main cooling fans have been removed. The two miner ASIC boards, each with top and bottom heatsinks are visible. Notice the thick accumulation of dust on the heatsinks and surrounding structures. This dust is a thermal insulator, potentially reducing the cooling effectiveness of the heatsink fins by an estimated 25% at this thickness. This will have a large negative impact on the thermal environment of the miner, as the heat generated in the miner ASICs that is conducted into the aluminum body of these heatsinks is partially blocked by the dust before it works its way into the passing cooling air. This causes a sort of "back up" of heat into the miner ASICs, greatly increasing their die temperature, reducing their performance, increasing their power draw, reducing their achievable clock rates and shortening their life, as well as potentially impacting the life of supporting circuits like PSUs

Reference KABOOM_0261.pdf[91] is a view of the interior of a miner with the back removed. The miner AIIC PC boards are sandwiched between the top and bottom heat sinks. There are six extruded aluminum heatsinks per miner board, three on top and three on the bottom. Spring loaded screws clamp the inner surfaces of these heatsinks to the top of the miner ASICs that cover the top and bottom surface of the PC boards. Notice at the boundary at the edges of the three heatsinks, the dust is a darker color. This is believed to be moisture condensation in the dust in areas of the miner with less airflow. This darker color may imply this particular dust is hygroscopic, meaning it absorbs water, which leaches minerals out of the dust and turns it into a sort of conductive mud. This is in direct contact with the circuitry on the surfaces of the miner board, and is very likely to cause shorts, current leakage, datalink errors, miscalibrations, and other performance problems.

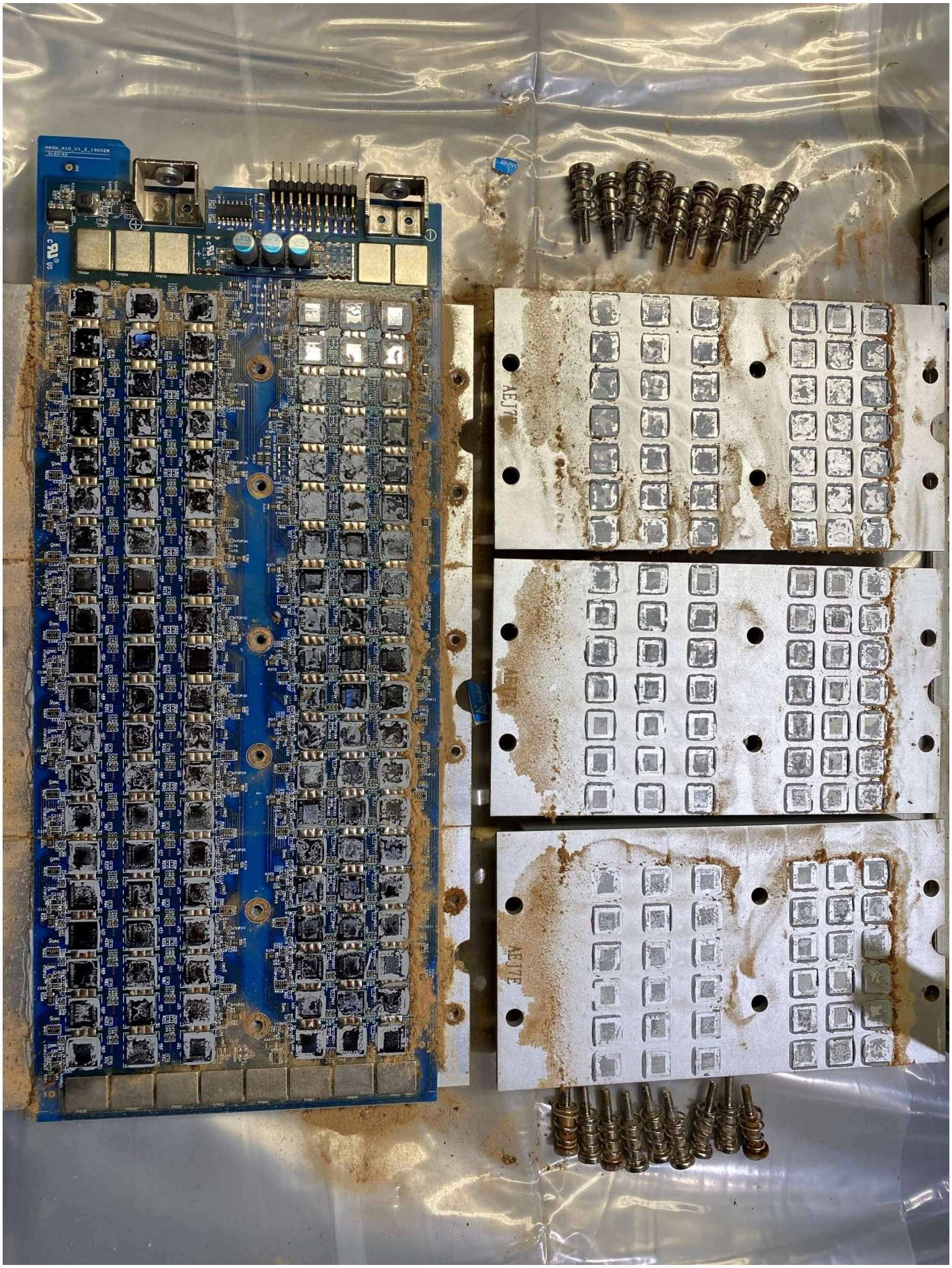

Figure 28 - ASIC Board and Heatsinks

Teardown photo Figure 28 - ASIC Board and Heatsinks shows one of the two miner ASIC boards from a miner chassis and its removed heatsinks. Power enters this board through the top busbar connectors, and is distributed to the 120 mining ASICs. The multipin connector at the top right of the board connects to a socket on the miner control board. The white substance visible on the underside of the heatsinks and on the mining ASICs is a thermal interface material called heatsink grease that improves thermal contact between the ASICs and the underside of the heatsink. The 18 screws with springs are an important part, as they regulate the contact pressures between heatsinks and boards. Three additional heatsinks identical to the three shown cover the backside of the board to dissipate a smaller portion of the heat that exits the underside of the ASICs and is conducted through the thickness of the circuit board. Notice the large amounts of red-brown dust accumulated on this board, especially on its right side, which is the inlet side nearest the main fans. This dust certainly impacts the cooling flow, and probably has negative impacts on the electrical connections of the components it comes into contact with.

6.8.7.7 Internal Condition of Management Module Boards

Reference KABOOM_0125.pdf[92] is a close-up of two contaminated circuit boards, one is the miner control board, and the other is part of the PSU. Notice the thick layers of dust that are likely contaminating the chips, connectors and circuit board traces, adversely impacting the operation of the miner chassis, its PSU or (likely) both.

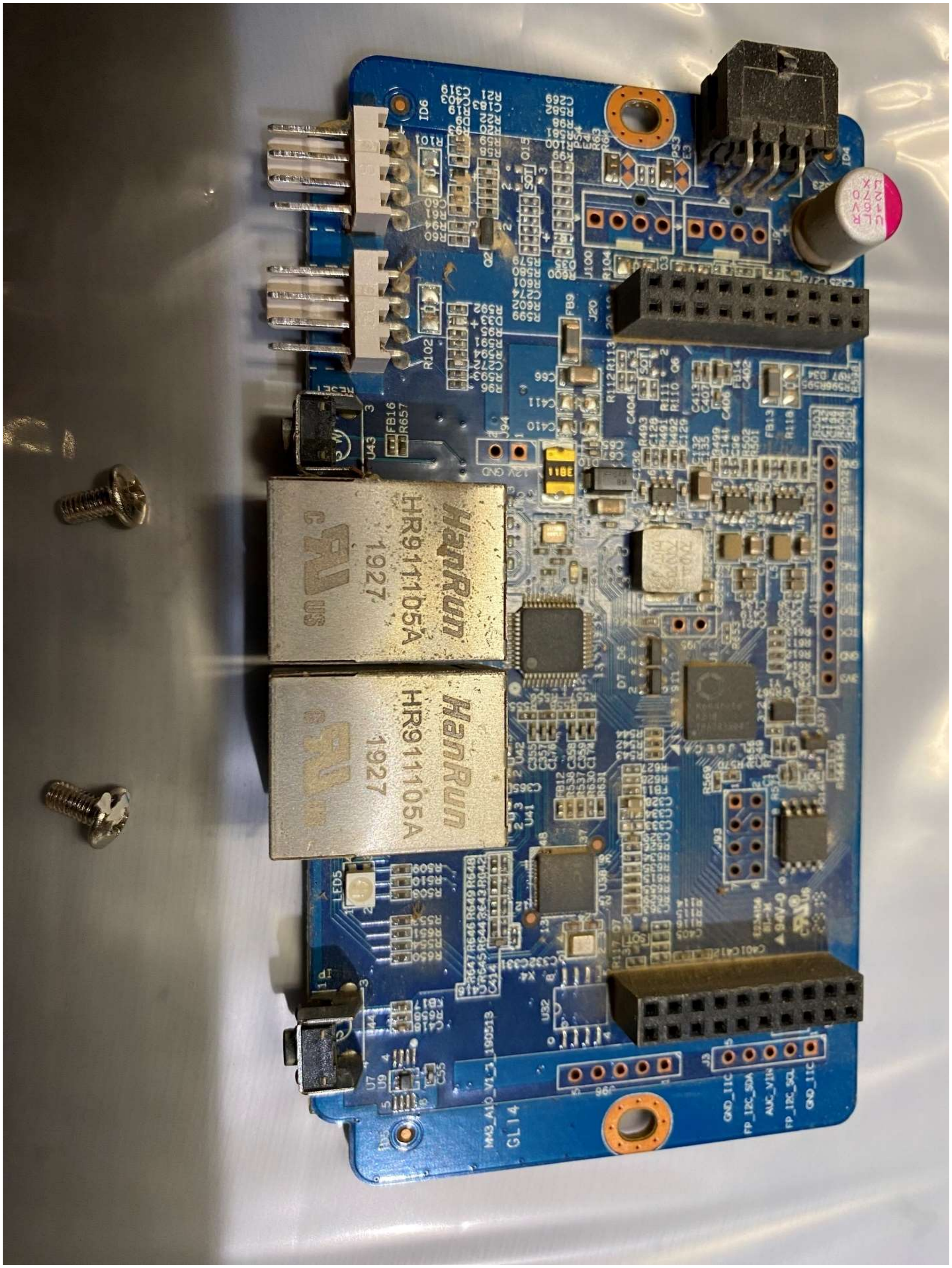

Figure 29 - Miner Control Board

Teardown photo Figure 29 - Miner Control Board shows the control board removed from a miner. Its key components include a Kendrite K210 main CPU with two 64-bit RISC-V cores, a five-port Ethernet switch from IC Plus, and a WIZnet COMW5 hard-wired ethernet controller. Note the dust surrounding the critical components, especially the fine-pitch pins of the Ethernet switch just below and to the right of the HanRun RJ-45 Ethernet jacks. The distance between these pins is smaller than the size of some of the conductive fragments discovered in dust samples, making short circuits on this board (and also similar fine-pitch components on the two miner ASIC boards) highly likely.

6.8.7.8 Condition of Fans and Fan Guards

Reference KABOOM_0117.pdf[93] shows two miner chassis primary cooling fans in bad shape. Dust has accumulated on most of their surfaces. Corrosion well beyond expected limits is evident on the two fan finger guards. Significant abrasion from dust and excess humidity is obviously present to cause this level of corrosion on coated steel in the span of only approximately one year of exposure. Although not directly visible here, if the dust infiltrates the fan bearings, they will quickly develop performance problems and premature failures. This particular dust is suspected to be quite abrasive, due to the tons of aluminum oxide power that were processed daily for decades at the Alcoa refinery less than a mile away.

6.8.7.9 Miner Teardown Conclusions

After careful analysis of the external and internal condition of five miners, I was unable to discover any latent design or manufacturing defects in the miners or their PSUs. The power required by the miner chassis (2361W) is well supported by the power supply output capacity (either 2601W, 2592W or 2600W, depending upon the power supply model), with a reasonable 10% engineering margin. The most striking conclusion of the miner teardown is the extraordinary amount of dust on the critical internal and external surfaces.

6.9 Technical Analysis of Probable Causes of Underperformance

This section will summarize the evidence presented in the above sections, and map it to specific failure mechanisms.

6.9.1 Failure Mechanisms

The predominant failure modes leading to the poor mining performance in the Rockdale datacenter are largely due to premature miner failures due to thermal / overheating issues. Secondary causes include the conductive or abrasive properties of the abundant dust, and various shortcomings in the design and operation of the datacenter by Whinstone.

6.9.2 Causes of Performance Deficits

The reason that the performance and revenue targets of the datacenter were not met is the unacceptably high failure rate of the miners. When a miner fails, it is disconnected from the miner pool, and the overall system has lower hashrate and therefore lower probability of discovering new bitcoins. Depending upon the exact failure mechanism of a miner, it can also contaminate the environment of adjacent miners, causing cascading failures.

6.9.3 Impact of Datacenter Site Location Choice

The location of the datacenter could have aggravated the failure modes of the miner fleet. The climate in this part of Texas is classified by ASHRAE as hot and humid, so the air entering the datacenter is often warmer than the 35°C (95°F) maximum input air temperature specification of the miners. See Figure 17 - Temperature Observations. The high humidity often experienced in this part of Texas would have reduced the effectiveness of the wet curtain walls (if they had ever been used), and contributed to the corrosion and potential dust problems. Finally, the specific plot of land the datacenter is located on could have been subject to soil contamination from the nearby abandoned aluminum smelter and coal fired power plant, making the character of the dust on the site more damaging.

6.9.4 Impact of Datacenter Building Design

The datacenter building and site are major contributors to the problems. The landscaping of the site during the months the miners were operational made little effort to control windblown dust, as there was no pavement adjacent to the buildings, and most of the earth on the 100-acre site had no groundcover or wind erosion prevention measures.

The buildings are basically long warehouses, where little attempt was made to optimize the physical environment for individual miners or isolate them from nearby environmental problems. The design of the hot aisle and its clearstory ventilation louvers is especially problematical, because the area of the exhaust ports is approximately three times too small, with no exhaust fans, creating significant restrictions to airflow.

This restriction was a primary cause of one of the most common miner failure modes experienced in Rockdale. Because of the exhaust air restrictions, the primary miner chassis cooling fans (40,000 of them) were moving air from the cold aisles, through the hot ASIC miner boards, to the hot aisles. But because the miner PSU cooling fans were smaller and lower power, they couldn't produce adequate flows at the backpressures caused by the miner chassis fans, starving the PSUs of their required cooling flows, and causing overheating and premature failure of the PSU internal components. Had adequate exhaust louver area or booster fans been available in the hot aisle, the PSU fans may not have experienced this starvation, and the miner reliability would have been much better.

6.9.5 Impacts of Cooling Airflow Design and Implementation

The cooling air paths are designed to flow from the intake louvers, bug screens, wet curtain wall, across the cold aisle, through the miners, and up the hot aisle through the exhaust louvers. The only sources of energy driving circulation in this path are the cooling fans in the miners. These proved inadequate to provide the high-volume airflows these miners need to efficiently cool. Booster fans in the cold aisle intake paths, in the hot aisle exhaust paths, or both could have improved the airflow and miner reliability. As demonstrated in a deposition transcript from David Schatz[94], Whinstone never installed these booster fans.

6.9.6 Impact of Wet Curtain Wall Operation Failures

One of the contributors to the overheating problem was the failure of Whinstone to correctly operate the wet curtain walls during the times when the outdoor air exceeded 29°C (84°F). Historical weather data shows the maximum daily temperature exceeded this value 205 days during the 587-day deployment of these miners. The maximum outdoor temperature recorded during the deployment interval was 102°F (39°C) on August 16 and 28, 2020. This obviously greatly exceeded the allowable

input temperature from the miner specification and also the terms of the hosting agreement contract. This sort of exposure to excessive heat can have a cumulative effect on semiconductor reliability, and was a strong contributor to the unacceptably high failure rates of the miner chassis internal components and their PSUs

According to a deposition from Heath Davidson,[95] there were delays in setting up the system to pump cooling water from Alcoa Lake to operate the wet curtain walls. There were also delays in construction of the wet curtain walls and the water distribution infrastructure needed to operate them. During the interval when this water was unavailable (despite Whinstone's assurance that the datacenter was ready for full operation) it is likely that many of the miners were damaged, or at least their life was substantially reduced. Whinstone claims that a freeze damaged components of the wet curtain wall, and therefore it was impossible to operate it.[96] No explanation was offered as to why the needed repairs to this damage were not promptly made.

6.9.7 Impact of Poor Miner Intake Air Quality

The cooling air drawn into the miners was excessively dusty, as evidenced by the thick layers of dust on the datacenter floors, equipment racks, external miner surfaces, and critical internal miner components. The serious nature of this contamination problem was validated in the miner teardown and laboratory analysis of dust samples. This dust potentially contributed to the miner failure in at least five ways:

- insulating the heat transfer surfaces of the very critical miner chassis and miner PSU heatsinks
- creating unwanted conductive paths and potentially arcing in internal circuitry
- preventing necessary conductive paths in connectors, relays and similar components
- abrasive impacts of the dust on cooling fan bearings and various miner parts
- corrosive impacts of dust on structural and electrical miner components

Together these impacts represent another key failure cause.

6.9.8 Impact of Lack of Air Filters

Many of the negative impacts of the dusty environment could have been at least partially mitigated through the installation of air filters to remove the dust from the cooling air. These filters could have been placed in three locations: in the building air entrances before the wet curtain walls (preferred), at the exit of the wet curtain walls before the cold aisle, and/or at the input fans of each individual miner.

Whinstone knew of the dust problem, as evidenced in an exploration of polyester filter media,[97] but failed to take appropriate corrective actions. One possible reason is that filters of the required arrestance (at least MERV 8) would have created extra resistance to the airflow, reducing the effectiveness of the already marginal cooling scheme. A second problem could be that because of the extremely dusty nature of the site, these filters would quickly become loaded with dust and obstructed, requiring constant maintenance and frequent replacement (adding significantly to the operational costs of the building, a cost Whinstone was apparently unwilling to bear).

6.9.9 Impact of Miner Air Recirculation

Whinstone was not careful about maintaining the integrity of the sequestration barrier between the hot and cold aisles (as evidenced by the gaps appearing in numerous hot aisle photos). This caused hot exhaust air from the pressurized hot aisle to find unintended paths back around the miners to the cold aisle to mix with the incoming cooling air, preheating it to well above the allowable miner inlet

temperature. Whinstone also failed to identify and repair miners with failed fans, PSUs or control boards, allowing hot aisle air to pass through the miners backwards to the cold aisle. Apparently, as shown on page 76 of the Heath Davidson deposition[95], it was their policy to leave failed miners in place, allowing hot aisle air to flow backwards to the cold aisle. Whinstone should have sealed all gaps, and periodically inspected for this reverse airflow condition and either repaired the components, or removed the impacted miner and tightly plugged the gaps in the sequestration wall.

6.9.10 Impact of Improper Cleaning and Maintenance

The datacenter and its grounds were not adequately cleaned. Thick mats of dust accumulation were evident on many surfaces. The internal components of the miners were unacceptably dusty (as demonstrated in the teardown analysis shown in section 6.8.7. Whinstone should have better controlled outdoor dust on the site, and cleaned the floors and equipment racks much more thoroughly and frequently. Miners with this level of internal dust accumulation should have been "blown out" periodically in an attempt to preserve the capabilities of their heat sinks and reduce the impact of dust on circuits and parts. As Whinstone failed to maintain the cleanliness dictated by datacenter best practices, there were significant negative impacts on the miners' performance and lifespan.

6.9.11 Impact on Miner Power Efficiency

The miners that were still left operating in this environment were not running at full power efficiency. Silicon chips (such as the ASICs inside the miners) draw more power, and run at slower clock rates as they heat up beyond their maximum temperature ratings. Some miners may have failed in a way that they were no longer doing useful mining work for the pool, yet were still drawing full power from the grid. Because SBI pays for its hosting charges based upon total power draw, these factors that make the miner fleet less power efficient represent an overcharge for the energy used for useful computations.

6.9.12 Departures From Industry Best Practices and Standards

The Whinstone datacenter infrastructure and operational practices departed from generally accepted industry best practices in several dimensions. Their building designs were not correctly sized for the thermal load installed inside them (especially the clearstory exhaust louvers). Industry best practices would be to choose a location and design the building and its features to correctly accommodate the equipment expected to be installed inside, and its maximum heat dissipation, plus some margin to cover unanticipated circumstances.

The wet curtain wall designed to cool the datacenter was not correctly weatherproofed, and therefore suffered frost damage that Whinstone chose not to repair. This type of cooling infrastructure will not perform well in humid environments like Rockdale. Maintenance of critical cooling systems, and performing emergency repairs quickly when they fail is a best practice that Whinstone did not effectively implement.

Input air temperature from the cold aisles was not limited below the 35°C / 95°F maximum input temperature expected by the servers (30°C or 86°F in turbo mode) or the 29.5°C required by the hosting agreement. Industry best practices are to continuously monitor the temperatures, flows and air quality in the cold aisle, racks, miners and ASICs with calibrated sensors, maintain complete log files of historical readings and correct the cooling system if any of these thousands of monitoring points are out of spec. There is no evidence of these sensors, logging, monitoring or adequate response in this datacenter.

Best practices for hot aisle / cold aisle sequestration were not adhered to. Many air leaks allowed hot exhaust air to recirculate around the servers and enter the cold aisle and thence preheating the cooling input flow to the miners, and these leaks apparently persisted for months. Better sealing systems should have been used. Also, large reverse flows happened in miners with non-operating cooling fans. Maintenance processes should have promptly discovered and repaired them, or at least provided airflow blocks or automatic one-way dampers to lessen this impact.

Dust infiltration into the datacenter was one of the most egregious violations of industry best practices. The outdoor environment was exceedingly dusty, and the windblown dust passed right through the bug screens and openings in the wet curtain wall to settle on and in the servers (and on many other surfaces in the datacenter). The bug screens will foul quickly with insects, windblown plant debris and trash, restricting intake airflow, and they were not designed for easy cleaning or replacement. Best practices would have required replaceable / cleanable air filters with at least MERV8 arrestance on the input air to the building, on the miner fan intakes, or both. Air intakes and exhaust ports should have been sealed during dust storm events.

Cleaning practices were totally inadequate. Best practices for datacenters would immediately and continuously clean any surfaces in the datacenter that had even a small amount of visible dust. Many places in the datacenter and inside the servers had several millimeter (0.1”) thick layers of dust accumulating on surfaces critical to the reliable operation of the miners.

Ongoing monitoring and prompt repair of any failed equipment in the datacenter is an industry best practice. In the Whinstone datacenter, at times up to 7000 miners had failed, and inadequate steps were being taken by the maintenance staff to return the fleet of miners to full strength (as required by the active remote hands agreement).

It is a best practice to keep the clients of a datacenter fully informed on its progress and status. Whinstone first misrepresented their planned capabilities and then failed to provide accurate status on several aspects of the initial deployment of the miners, including estimates of building completion and availability dates, accurate estimates of the timing of connection of mass power and water utilities, accurate estimates of miner installation dates and progress reports, operational parameters of the datacenter including accurate power use readings for billing, miner failure rates and failure modes, data network status, actions taken (or not taken) to correct various problems. If these communications were adequate at all stages of the deployment, SBIC would have taken many more proactive steps to protect their investment and maximize their revenue from the 20,000 miners left in Whinstone’s care.

6.9.13 Violation(s) of Hosting Agreement

The hosting agreement is a legal contract between SBIC and Whinstone spelling out agreements on the technical and business aspects of hosting 20,000 SBIC miners in the Whinstone Rockdale datacenter. Many aspects of this hosting agreement were willfully violated by Whinstone, especially the time to services schedules, 29.5°C maximum input air temperature guarantee, response time for “active hands” repair of failed miners, maintenance / cleanliness of the building interior, and violation of many industry-accepted best practices for datacenters.

6.10 Economic Analysis

6.10.1 Impact on Miner Efficiency

At the end of the deployment on June 28, 2021, about 2000 miners were unresponsive, and about 3000 were responsive but not hashing. Miners that were responsive and hashing were often hashing at lower than expected rates, because the system automatically throttled their performance down to reduce energy draw and overheating problems. This reduced the fleet hash rate to less than 60% of the expected value[37], creating a significant shortfall between the projected performance of the fleet (upon which the feasibility assessments and hosting contracts awards were made), and the actual fleet performance.

6.10.2 Impact on Power Efficiency

The poor conditions in the Rockdale datacenter caused the miners to run hotter, and therefore throttled to lower clock rates and PSU voltage settings. These lower settings had poorer watts/terahash rates than if the highest performance turbo mode operation was available. Also, a significant number of miners failed in ways where their hashing functions were not providing valuable results to the miner pool, yet they were drawing significant electrical power (which Whinstone was including in the monthly hosting charge calculations).

6.11 Conclusions

6.11.1 Summary

In summary, this report outlines the conditions at the Whinstone Rockdale datacenter, the installation of a fleet of 20,000 Canaan brand AvalonMiners owned by SBI in that facility, and the various performance and reliability problems experienced. The approximate flow of logic used in this report to collect and analyze evidence is shown in Figure 30- Flow of Reasoning.

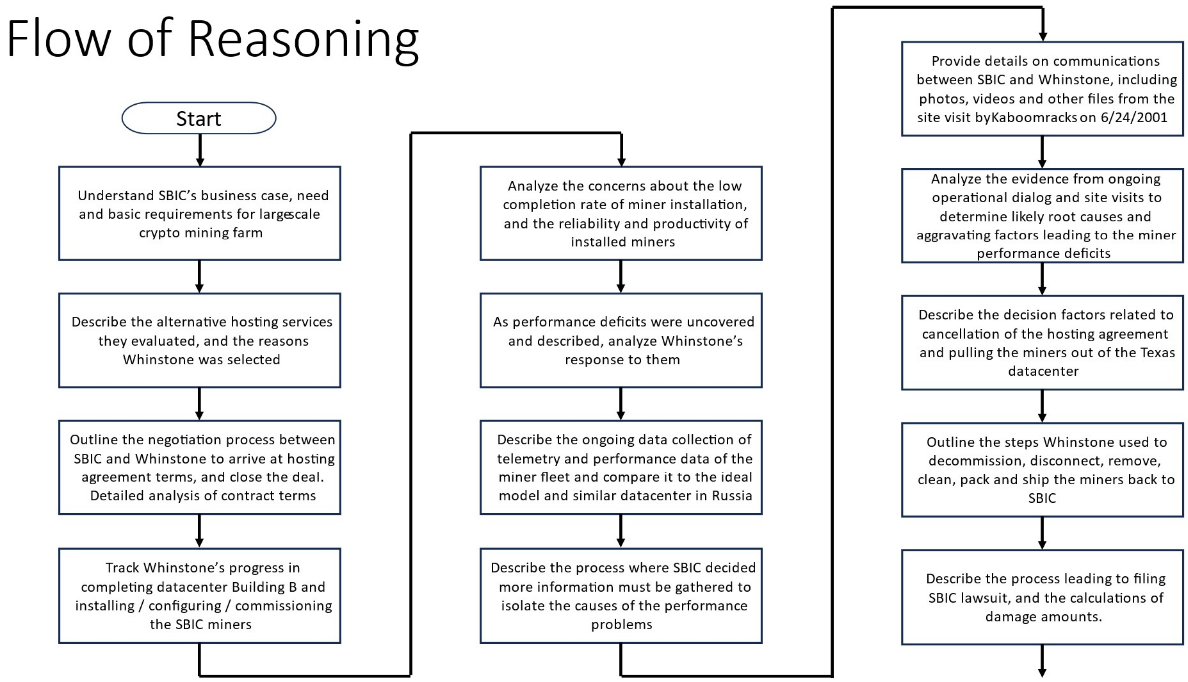

Figure 30- Flow of Reasoning

This flow considered several thousand items of evidence, consisting of computer files, text message thread transcripts, contracts, spreadsheets, data sheets, log files, climate observations, photos, videos, scientific laboratory reports, depositions and web sites. These items were organized, categorized, described and interoperated for significance in a spreadsheet[98]. Rigorous cross-references between these evidence items and the detailed analysis are provided by endnotes, with over 90 references listed in section 7.

The flow of reasoning leads to clear conclusions that Whinstone is liable for the performance problems experienced by the SBI fleet of miners installed in their Rockdale datacenter. Various design flaws, configuration problems, and poor operational procedures that significantly departed from the contracted hosting agreements and industry accepted practices led to a 45-55% reduction in the productivity of SBIs' miners.

End of Report

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By:

Charles C. Byers

Charles C. Byers

2s710 Wendelin Court

Wheaton, IL 60189

byerschuck1@gmail.com

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